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DRYLAND CROP-ROTATION and TILLAGE EXPERIMENTS

at the Colby (Kans.) Branch Experiment Station

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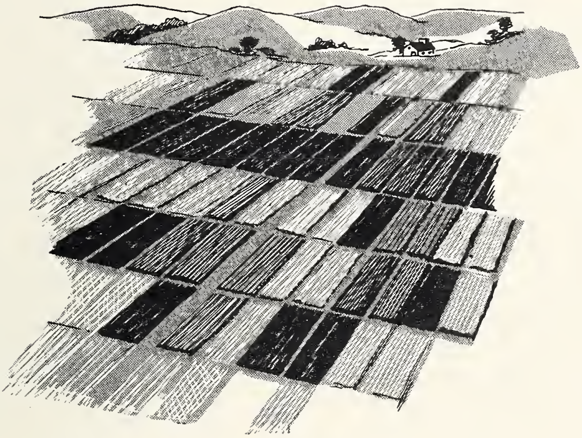
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with the Kansas Agricultural Experiment Station

Dryland Crop-Rotation and Tillage Experiments

at the Colby (Kans.) Branch Experiment Station

By J. B. Kuska, Agronomist, and O. R. Mathews,
Senior Agronomist, Soil and Water Conservation
Research Branch, Agricultural Research Service



UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with the Kansas Agricultural
Experiment Station

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Dryland Crop-Rotation and Tillage Experiments at the Colby (Kans.) Branch Experiment Station

**By J. B. Kuska, agronomist, and O. R. Mathews, senior agronomist,
Soil and Water Conservation Research Branch,
Agricultural Research Service**

This circular represents 36 years (1915–50) of experimental work in crop-rotation and tillage methods, conducted cooperatively by the United States Department of Agriculture and the Kansas Agricultural Experiment Station. The experiments discussed herein were conducted at the Colby (Kans.) Branch Experiment Station.

The work was actually started in 1914, but the results that year are not included in the results discussed in this circular, because the land had been uniformly prepared and crops were not grown under their designated tillage and sequence treatments. The work was carried on 1914–43 by the Division of Dryland Agriculture; 1944–48 by the Division of Soils, Fertilizers, and Irrigation; and 1949–51 by the Division of Soil Management and Irrigation. Similar experiments were conducted by these divisions at 18 other stations in the Great Plains. Dryland experiments are now conducted by the Soil and Water Conservation Research Branch, Agricultural Research Service.

Soil-moisture determinations to aid in the study of storage and use of soil moisture, as well as the recording of rainfall and other climatic factors influencing crop production, have been an integral part of this work. The yields of the various crops during the first 15 years the work was underway (1915–29) are summarized in a previous publication.[1]

The Colby Branch Experiment Station is located just outside the city limits southwest of Colby in Thomas County, Kansas. This county is in the northwestern part of the State; it is the second county east of the Colorado State line and the second south of the Nebraska State line. Colby is about 55 miles east of the western boundary of the State and about 43 miles south of the northern boundary.

The altitude at Colby is approximately 3,150 feet. Topographically, the county is an almost level plain, cut at infrequent intervals by intermittent watercourses.

Determinations based on the experiments at the Colby station are generally applicable to the uplands of a large area of the central

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[1] Kuska, J. B. methods of crop production at the colby (kans.) branch experiment station, 1915 to 1929. U. S. Dept. Agr. Cir. 184, 24 pp., illus. 1931.

Great Plains of northwestern Kansas, southwestern Nebraska, and east central Colorado.

The native sod of this area consists mainly of buffalo and grama grasses.

Winter wheat is the principal crop, occupying a larger acreage than all other crops together. This is also the main barley-producing section of the State. Until recently, corn was grown fairly extensively, but it is being largely replaced by grain sorghums of the combine type. Forage sorghums are grown on a limited acreage on most farms, mainly for roughage.

SOIL

The soil is of the Chestnut group, now classed as Sherman silt loam, though formerly classed as Colby silt loam. It is representative of the prevailing types of this region. The surface soil (0 to 7 inches) is a brown silt loam with about 60 percent of silt, 14 percent of very fine sand, and 25 percent of clay.[2] A buried soil, much blacker in color than the present surface soil, occurs over the area ranging in depth from almost at the surface to 3 to 4 feet below the surface. On the station its depth below the surface is about 2 feet.

Where the surface soil merges into the subsoil, there is a compact layer of heavy silt loam ranging in thickness from about 2 to 8 inches. This layer contains varying quantities of carbonate concretions. Below this is the parent material which is a loose, mealy, unaltered loess that extends to a depth of many feet.

The soil is friable and easily worked, especially when the proper moisture conditions exist. A cloddy surface, which is desirable to prevent soil blowing and to facilitate the penetration of water, can be formed fairly readily by working the land when wet. The soil when dry plows up cloddy and lumpy, but it works down easily after rain. It blows readily when the surface is dry and finely pulverized. Wind erosion is an ever-present hazard, especially in years of low precipitation.

The soil is fertile and seems amply supplied with the essential plant-food elements. Crop production has been limited by moisture rather than by soil fertility.

CLIMATE

Climatological records have been kept at the Colby station since it was established in 1914. Temperatures are recorded in a standard United States Weather Bureau shelter, and precipitation is measured in a standard Weather Bureau gage. Wind velocity is determined from a Robinson 4-cup anemometer exposed at a height of 24 inches. Evaporaton is recorded by daily micrometer measurements of the change in water level in a tank 24 inches deep and 6 feet in diameter, sunk to a depth of 20 inches in the ground, with the water level maintained at approximately ground level. The vapor pressure and the temperature of the dewpoint are obtained from psychrometer readings taken 3 times daily during the growing season, April 1–September 30.

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[2] Mechanical analysis of virgin profile of Sherman silt loam made in the Soils Laboratory, Beltsville, Md.

Precipitation and temperature records for Colby since 1888 are available from the United States Weather Bureau. The Colby station records for the monthly, seasonal (April–September), and annual precipitation for the 37 years from 1914 to 1950, together with the average for the period are shown (table 1). Averages from the Weather Bureau records and the Colby station records covering a period of 63 years (1888–1950) are also included.

Precipitation

The average annual precipitation for the 63 years from 1888 to 1950 has been 18.03 inches and for the 37-year period since the establishment of the station in 1914, 18.48 inches. The seasonal (April–September) precipitation for the 37 years has averaged 14.24 inches. More than three-fourths of the annual precipitation falls during the 6-month period which approximates the growing season.

Precipitation has been recorded at this station on an average of 119 days a year; a trace has been recorded on 44 days; and amounts of 0.01 inch or more on 75 days. Approximately 45 percent of the precipitation has been in quantities of 0.50 inch or less; 28 percent, from 0.51 to 1 inch; 14 percent, from 1.01 to 1.5 inches; 7 percent, from 1.51 to 2 inches; and 6 percent, over 2 inches. Much of the precipitation falls in hard rains, resulting in considerable runoff and erosion. In the 37 years, however, there have been only 4 rains of 3 inches or more; these occurred in 1914, 1941, 1944, and 1946. The heaviest rain ever recorded at this station was 5.15 inches on July 25, 1941.

Rains have been concentrated in certain periods. The precipitation for the year is shown by 10-day periods (fig. 1). Average precipitation gradually increases from its low winter level to a maximum in late May and early June. It then declines gradually until it reaches the winter level in November.

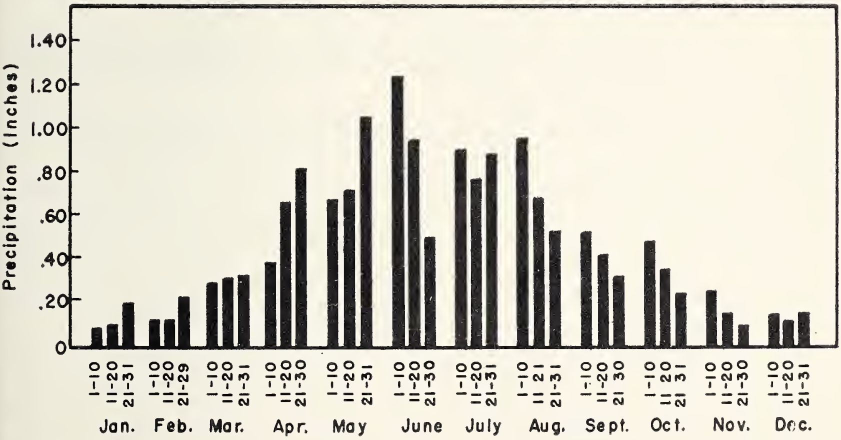

FIGURE 1.—Average precipitation by 10-day periods, Colby (Kans.), 1914-50.

TABLE 1.—*Monthly, seasonal, and annual precipitation in inches at the Colby (Kans.) Branch Station for the 37-year period, 1914–50; and the 63-year average for Colby from the United States Weather Bureau, 1888–1950; and the Colby Branch Station, 1914–50*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Seasonal (April–September)	Annual
1914	0.05	0.45	0.21	1.21	3.07	2.32	5.01	1.85	0.52	0.87	(1)	0.51	13.98	16.07
1915	.38	1.49	1.43	3.61	4.55	4.03	6.60	4.17	.67	1.10	0.48	.48	23.63	28.99
1916	.55	.05	.33	2.03	1.33	3.15	2.07	1.48	.40	.62	.21	.37	10.46	12.59
1917	.12	.20	.56	1.66	2.01	1.42	3.07	5.78	4.25	.28	.42	.20	18.19	19.97
1918	.77	1.79	1.34	1.05	2.16	.19	1.86	1.88	2.16	2.87	.21	2.63	9.30	18.91
1919	(1)	1.57	.59	2.80	2.23	2.47	3.95	.65	2.07	.82	1.63	.19	14.17	18.97
1920	.23	.31	.46	3.74	2.42	5.68	4.19	3.75	2.56	2.71	.27	1.31	22.34	27.63
1921	1.15	.03	.58	1.88	1.85	3.52	4.24	2.23	2.80	.45	.18	.46	16.52	19.37
1922	.18	.35	1.26	4.08	2.55	1.34	2.74	1.38	.43	.08	3.13	.02	12.52	17.54
1923	.05	.18	.88	2.80	6.28	3.27	3.46	3.55	1.87	3.33	.12	.75	21.23	26.54
1924	.22	1.82	1.78	.48	1.30	.80	1.77	3.09	1.78	.95	.14	1.97	9.22	16.10
1925	.23	.25	.47	1.44	3.52	1.07	1.50	3.50	2.00	.82	.16	.39	13.03	15.35
1926	.52	.12	.50	.87	2.08	1.57	.57	2.04	.92	.22	.83	.34	8.05	10.58
1927	.11	1.26	1.59	3.51	.43	3.75	2.00	1.87	2.68	.25	.10	.45	14.24	18.00
1928	(1)	.48	1.53	.89	4.53	5.40	2.66	1.19	.29	2.06	.65	.06	14.96	19.74
1929	.06	.76	.13	3.15	3.25	1.96	1.07	1.13	3.02	1.70	1.81	.02	13.58	18.06
1930	.20	.32	.08	2.41	5.11	3.29	1.57	4.15	.73	5.54	1.23	.15	17.26	24.78
1931	0	1.51	2.14	.92	1.32	2.00	2.77	1.49	.35	.93	1.06	.04	8.85	14.53
1932	.38	.57	.34	2.05	1.46	3.98	3.26	1.03	.83	.34	.27	.35	12.61	14.86
1933	(1)	.08	.70	2.22	2.56	.14	3.65	4.92	.76	.30	.94	.42	14.25	16.69
1934	.06	.87	.51	.36	.92	1.59	.41	1.40	.75	.09	.18	.23	5.43	7.37
1935	.01	.30	.33	.29	2.92	3.14	.50	.89	1.69	.11	1.17	.14	9.43	11.49
1936	.14	.30	.21	1.07	3.48	.46	.31	1.56	2.49	.45	.02	.43	9.37	10.92
1937	.33	.17	1.47	1.01	2.12	2.70	1.50	1.04	1.69	1.50	.09	.26	10.06	13.88

1938	.21	.12	1.68	1.22	4.37	2.61	5.51	1.04	.83	.06	.16	.02	15.57	17.82
1939	.34	.87	2.99	1.68	1.83	1.56	1.08	1.72	.43	(1)	.12	1.02	8.30	13.64
1940	.47	.19	2.42	.90	1.74	1.15	1.27	3.41	1.53	.51	.82	.37	10.00	14.78
1941	.79	.21	1.00	3.93	2.95	5.23	10.80	.77	3.05	.75	.30	1.35	26.73	31.13
1942	.26	.76	1.20	4.82	.94	3.99	.95	2.92	1.49	2.23	.52	.77	15.11	20.85
1943	.10	.38	.46	2.33	1.76	3.04	.84	3.69	.83	.51	.09	.32	12.49	14.35
1944	1.77	.51	1.68	6.36	1.69	5.32	5.46	.61	.43	.96	1.27	.38	19.87	26.44
1945	.81	.27	.14	3.19	3.13	3.50	1.23	5.73	1.13	.26	.17	.09	17.91	19.65
1946	.11	.02	2.69	.82	3.44	4.57	4.03	.91	.72	6.65	3.13	.03	14.49	27.12
1947	.36	.44	.87	1.65	3.35	4.46	.78	.99	.51	.36	.65	.75	11.74	15.17
1948	.33	.46	2.02	1.30	2.35	4.26	3.58	4.16	1.22	.28	1.32	.36	16.87	21.64
1949	.55	.49	2.29	1.57	4.99	6.59	3.89	4.22	.43	1.13	.10	.07	21.69	26.32
1950	.20	1.54	.43	.94	1.93	1.09	3.51	5.31	.56	.15	.03	.13	13.34	15.82
Average:														
1914–50	0.33	0.57	1.06	2.06	2.65	2.88	2.80	2.47	1.37	1.14	0.65	0.48	14.24	18.48
1888–1950	.31	.56	.98	2.11	2.48	2.98	2.64	2.35	1.42	1.07	.60	.50	14.00	18.03

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[1] Trace.

There are exceptions, however, to the general trend. The rainy period in late May is preceded by a period that is relatively dry for the season. This distribution of spring precipitation seems to be very favorable for production of winter wheat. The dry weather usually checks its straw growth, and the rains during late May are timely for heading. The rainy period continues through the first 3 weeks in June.

Rains have not been as frequent in June as in late May, but they have usually been heavier. They are important to small-grain crops and sorghums, as well as to moisture conservation in summer fallow. They are frequently so heavy that they cause an unnecessary amount of straw growth in small grains, often resulting in considerable lodging. This period of June is planting time for the sorghums. Sorghum stands may be poor because of heavy rains after planting; or planting may be delayed by rains, making the crop late.

In fallowing, it is important that the surface of the ground be in shape to take in and hold as much of the moisture from late May and early June rains as is possible and to make sure that weeds are not permitted to dissipate it. The plowing under of weeds in May before this long period of heavy precipitation, rather than after it in June, makes a great difference in the yield of crops on fallow.

This rainy period is followed by the driest 10-day period of the summer, June 21–30. This is the critical period for the wheat crop. If the soil is short of moisture, yields and quality may be reduced sharply. With abundant moisture in the soil, good crops of high-quality wheat have often been matured during this period. This is an opportune period for killing weeds on fallow and in row crops before wheat harvest begins. The first period in July is usually one of frequent, but not heavy, precipitation.

The dry periods, which usually start about the middle of August and continue, with only occasional interruptions, through fall and winter, are not especially favorable to the development of corn and sorghums. After the first week in September, the average precipitation for every 10-day period has been less than one-half inch. Winter wheat does not always become well established in the fall, but the dry weather is favorable for maturing corn and sorghums.

During the 63-year period for which records are available, the annual precipitation has ranged from 6.62 inches in 1910 to 31.13 inches in 1941. The precipitation since the establishment of this station has followed 3 distinct patterns. From 1914–30, there were 5 fairly dry years and 4 extremely wet ones, with 8 intermittent years that were moderately wet. In the 10-year period 1931–40, all years were below normal in precipitation. Next to the year 1910, the year 1934, with a total of 7.37 inches, was the driest year on record. From 1941–50, there was a 10-year wet period, with only 3 years below normal. The 3 years of subnormal precipitation were spaced fairly evenly over the 10-year period, and were among the best producing years because of abundant moisture in the soil from preceding wet years. The year 1947, with a total precipitation of only 15.17 inches, was one of the best crop years in the history of the station.

The average precipitation for the first 17 years (1914–30) was 19.36 inches; for the next 10 years (1931–40) it was 13.60 inches; and for the last 10 years (1941–50), it was 21.85 inches. The average for the last

20 years was 17.72 inches; this is 1.64 inches less than for the first 17 years, and 0.76 inch less than for the entire 37-year period. During the dry thirties, crop yields were reduced so much that averages for the 36 years, including the wet years in the forties, were appreciably below those of the first 17 years.

In the region covered by this study, hailstorms occur over limited areas in most years, especially during periods of heavy rainfall. Hail damage during the summer is heavy over wide areas in some years.

The average snowfall for the 37 years was 27 inches, ranging from 9.9 inches for the winter of 1937–38 to 54.1 inches for the winter of 1943–44. March, with an average of over 7 inches, is the month of heaviest snowfall. February is next, with an average of 5 inches. Although precipitation for the cold 6 months (October–March) is less than a fourth of the total precipitation, it is of considerable importance in crop production. In some years, late-fall rains and winter snows and rains have been important factors in bringing the winter wheat safely through the winter. Snows are important in moisture conservation. When the surface of the soil has abundant vegetative cover or is rough enough to catch and hold snow, a high portion of the winter's precipitation is stored in the soil.

Evaporation

The average monthly and seasonal evaporation at the Colby (Kans.) Branch Station, 1914–50, is shown (table 2). Detailed monthly records are shown (appendix table 21).

TABLE 2.—*Average monthly and seasonal evaporation; average monthly and annual mean, mean maximum, and mean minimum temperatures; and average monthly and annual wind velocity, Colby (Kans.), 1914–50*

Item	January	February	March	April	May	June	July	August	September	October	November	December	Total, or average
Evaporation inches[1]	---	---	---	4.96	6.28	7.77	9.37	8.26	6.32	---	---	---	42.96
Temperatures:													
Mean ° F	27	32	39	50	59	70	77	75	66	53	39	29	51
Mean maximum ° F	40	45	52	63	72	83	92	89	81	68	53	42	65
Mean minimum ° F	13	18	25	36	46	56	62	60	51	38	24	16	37
Wind velocity m. p. h.	6.1	6.5	7.8	8.6	8.0	7.0	6.2	5.8	6.4	6.0	5.9	5.8	6.7

[1] Evaporation was measured in a Plant Industry type evaporation pan, 6 feet in diameter and 20 inches deep, sunk in the ground to a depth of 20 inches and kept filled with water to about ground level.

The average evaporation for the 6-month period April 1–September 30 was 42.96 inches. It ranged from 31.66 inches in 1915 to 57.45 inches in 1934. The average evaporation was approximately

3 times the average precipitation for the 6 months. In individual years it ranged from 1.3 times the precipitation in 1915 to over 10 times the precipitation in 1934. Evaporation is an important factor in the storage and use of soil moisture and in crop production. It depends on various factors, including temperature, wind velocity, and humidity. It is something of an index to climatic factors, other than precipitation, which influence crop production. It tends to vary inversely with precipitation.

Temperature

Detailed monthly mean temperature data are shown (appendix table 22). The average annual mean temperature (table 2) for the 37-year period, was 51° F. The mean for the 6-month period April 1–September 30 was 66°, the mean maximum 80°, and the mean minimum 52°. As a rule the day temperatures are rather high during the summer, but the nights are comparatively cool. In the winter sudden drops in temperature from warm to subzero sometimes occur and are a hazard to winter wheat and winter barley, fruit buds, and even trees. The extreme temperatures recorded at Colby were 113° on July 25, 1940, and −31° on February 12, 1899. The temperature dropped from 70° to zero overnight on January 17–18, 1950.

The average length of the frost-free period for the years 1893–1950 was 160 days. The average date of the last killing frost in the spring was May 2, and that of the first killing frost in the fall was October 9. The earliest date of the last killing frost in the spring was April 10, 1942; the latest, May 28, 1947. The earliest date of the first killing frost in the fall was September 7, 1898; the latest, November 2, 1907 and 1937. The shortest frost-free period since the establishment of the station was 135 days in 1916; the longest, 190 days in 1937, 1939, and 1941. (See appendix table 23.)

A late frost in the spring often seriously damages the fruit crop, kills an early crop of weeds, and occasionally freezes back the spring-sown small grains and corn. Late frosts have damaged the winter-wheat crop in some years, mostly by checking development of the grain. The first killing frost in the fall is an important factor in sorghum production and, to a lesser extent, in the maturing of corn. The growing season is usually barely long enough to mature even the early varieties of sorghums. The uncertainty of maturing a promising crop is one of the factors that hold down the sorghum acreage in this area.

Wind Movement

The average wind velocity, measured 2 feet above the surface of the ground, was 6.7 miles per hour (table 2). The highest monthly average (appendix table 24) was 8.6 miles per hour for April, followed by May with an average of 8.0 and March with an average of 7.8. Average velocities of this order include many days or portions of days with much higher velocities. The low months were August and December, each with an average of 5.8 miles per hour. Higher wind velocities often cause damage by soil blowing during the late winter and early spring and occasionally at other times of the year. Hot winds during the summer sometimes injure growing crops severely.

High winds during snowstorms in winter are among the hazards of livestock production in this area.

The soil in this section is considered only moderately susceptible to erosion by wind; but when the surface has become finely pulverized and dry, it blows readily. High winds frequently drift the soil from bare fields into stubble fields and roadside ditches, fence rows, and other places where it can lodge. The most serious damage usually occurs when the soil surface is not adequately protected, and winter wheat or other small grains may be covered over or blown out. Young plants of winter wheat and surface-planted sorghums are occasionally damaged by soil blowing following dashing rains.

At the time this station was established, several thousand acres in the vicinity had been blowing for approximately 2 years, and even the sod in many of the pastures had been destroyed. A portion of the land included in these experiments had been eroded and was in a blow condition when the plots were laid out. Some of the surface soil had been blown off and accumulated in drifts on adjacent areas. Yields on the eroded land have not been appreciably different from those on land where little or no erosion occurred. The crops on land where drifted soil had accumulated suffered more severely in times of drought than on locations that were not eroded or on land where some of the surface had been blown off.

During the dry years from 1933–40, this section of the Great Plains was subject to frequent duststorms and serious wind erosion. In most years soil blowing can be prevented or controlled by timely working of the land with tillage tools that leave crop residues on the surface, or with tools that roughen or ridge the surface and leave it cloddy. There are periods, however, when there is a succession of dry years in which vegetative growth is so sparse that there is little or no vegetative cover or crop residues to protect the soil. During such periods, controlling soil blowing is difficult. During a protracted drought of several years, soil becomes so finely pulverized and loose after several workings that soil blowing and duststorms persist until precipitation becomes abundant enough and frequent enough to start vegetation and get it established. Much progress has been made in the control of soil blowing, but it remains a constant threat requiring vigilant attention.

Vapor Pressure

The average monthly and annual vapor pressure is given (appendix table 25). The vapor pressure, subtracted from the vapor pressure of the mean temperature for the same day or period, gives the quantity by which the air lacks being saturated.

THE EXPERIMENTAL FIELD

The experimental field covers approximately 42 acres. It is nearly level, with a slight slope to the east. Heavy rains drain off readily, and little soil washing takes place except in the roadways. These have been lowered somewhat to carry off water and prevent the water from one block of plots from draining across the roadway to plots farther down the slope.

According to the best information available, the buffalo-grass sod was first broken by plowing about 1885. The land was permitted to go back to sod in the early nineties and was broken again in 1905. Since then, the land has been farmed continuously.

A diagram of the field is shown (fig. 2) and a general view (fig. 3).

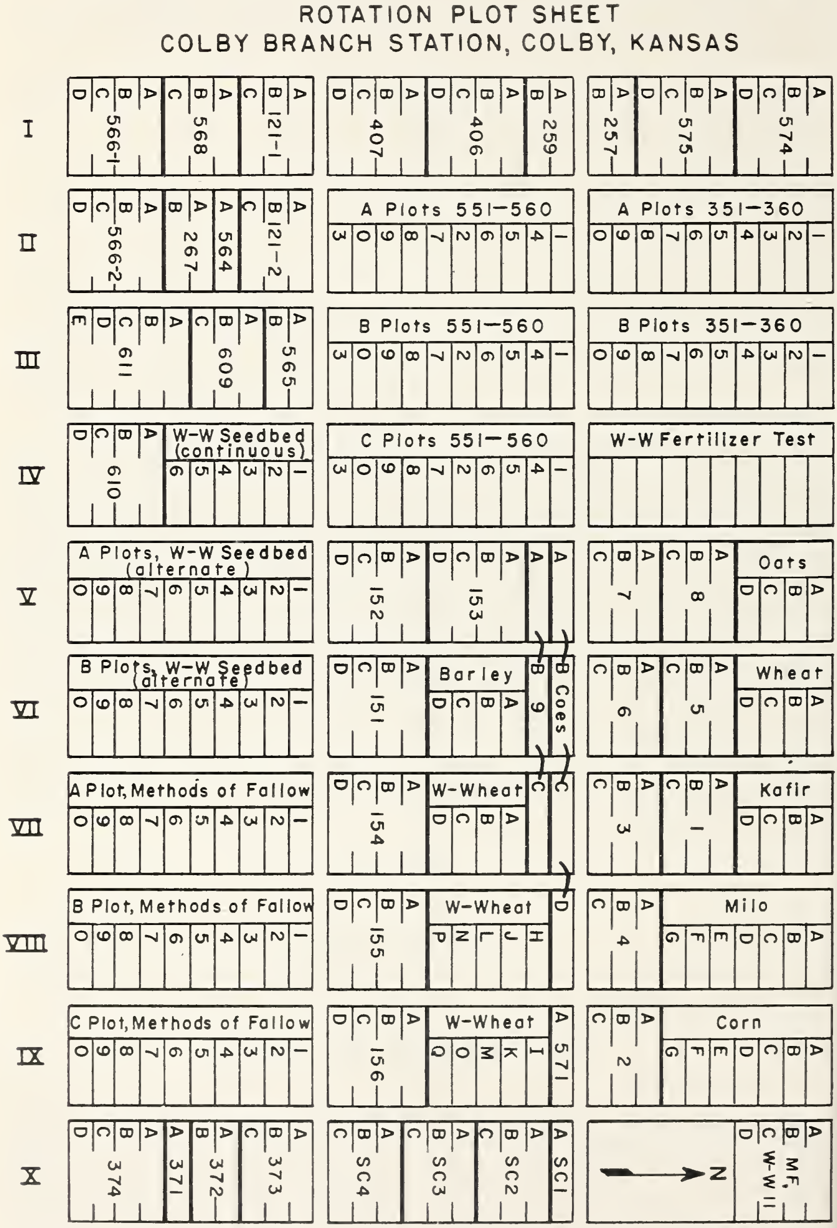

FIGURE 2.—Diagram of the crop-rotation field at the Colby (Kans.) Branch Experiment Station.

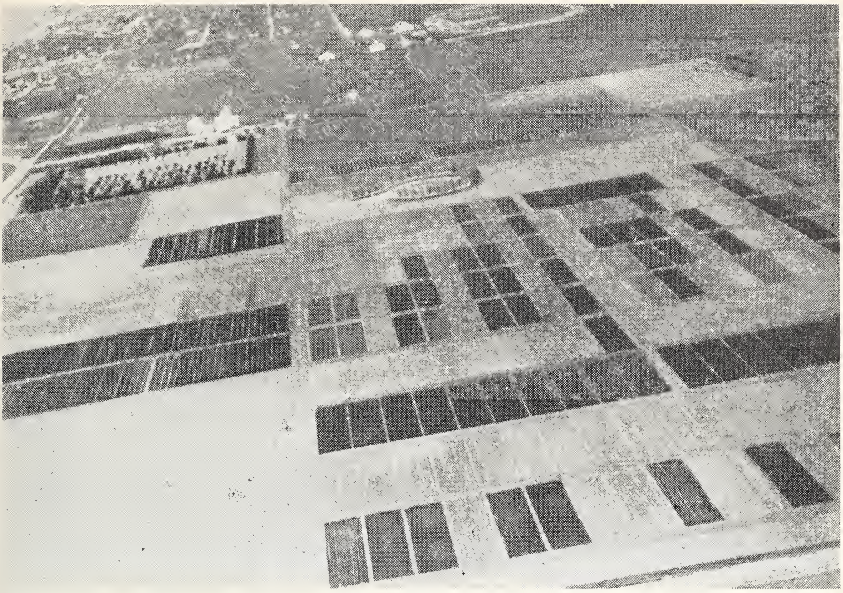

FIGURE 3.—Aerial view of the crop rotation field at the Colby (Kans.) Branch Experiment Station. The station farmstead and the town of Colby are in the left background. (North is toward the right.)

In general, rotations are indicated (fig. 2) by a number and the plots within a rotation by letters, the length of the rotation being indicated by the number of letters. The 2-year rotations are represented by the letters A and B; the 3-year rotations by A, B, and C; and so on. Two groups of rotations, 351–360 and 551–560, are arranged differently. In these, the plots are listed by single numbers arranged vertically; these numbers represent the last digits in the series of A plots (as, 1 for 351; 2 for 352; and so on). Continuous-cropping groups are indicated by the name of the crop, and the treatments within the group by letters. In the tillage (seedbed) and methods-of-fallow groups, treatments are represented by single numbers.

Field experiments were started in 1914 with 160 plots. Other plots were added from time to time, and a number of changes and substitutions were made in the original rotations. Every crop and tillage method was represented every year. Of the 294 plots in 1950, 140 were in winter wheat, 4 in spring wheat, 10 in barley, 10 in oats, 28 in corn, 25 in milo, 3 in kafir, 4 in Coes sorghum, 5 in Early Sumac sorgo, 1 in beans, and 64 in fallow. Other crops grown on the plots for part of the 37-year period were field peas and rye (for green manure) and feterita.

PLOT SIZE AND ARRANGEMENT

The experiments were conducted on 1/10-acre plots, 2 by 8 rods. The plots were separated at the ends by 20-foot roadways and at the sides by 4-foot alleys. The alleys were cultivated and kept free of vegetative growth.

Variety tests, rate- and date-of-seeding tests, and experiments with crops not included in the rotations have been conducted by the State of Kansas on other land; these are not included in this circular.

A standard variety of each crop was used, and all plots of a given crop were seeded to the same variety. The variety of each crop used in the rotations and the years in which it was grown are listed (table 3).

TABLE 3.—*Varieties of the different crops grown on the crop-rotation field at the Colby (Kans.) Branch Experiment Station*

Crop and variety	Years
Winter wheat:	
Turkey	1914–16
Kanred	1917–46
Comanche	1947–50
Spring wheat:	
Beloturka (durum)	1914–29 1932–36
Kubanka (durum)	1930–31
Local durum	1937
Reward	1938–50
Oats:	
Kherson	1914–29
Kanota	1930–50
Barley:	
Local 6-row	1914–37
Flynn	1938–50
Rye: Common winter	1914–46
Peas: Field	1914–46
Corn:	
Colby Bloody Butcher	1914–34
Colby Yellow Cap	1935–50
Milo:	
Dwarf Yellow	1914–37
Colby	1938
Disease-Resistant Day	1939–44
Disease-Resistant Colby	1945–50
Kafir:	
Dwarf Blackhull	1914–21
Dawn	1922–30
Western Blackhull	1931–50
Feterita: Standard	1917–45
Sorghum: Coes	1946–50
Sorgo: Early Sumac	1932–50
Beans:	
Pinto	1919–34
Great Northern	1935–50

Variety tests conducted at this station indicated that, with the possible exception of oats, the varieties used have been among the highest yielding. Since the Kanota variety of oats was introduced, it has outyielded Kherson consistently and was substituted for Kherson in 1930.

Whenever possible, the different crops were seeded at the time considered optimum for them. Winter wheat was seeded at the rate of 3 pecks to the acre; spring wheat, 1 bushel; oats, 1½ bushels; and barley, 1 or 1¼ bushels. The row crops were planted in 40-inch rows with a surface planter or a lister, depending on the rotation.

YIELDS OF DIFFERENT CROPS

Average Yields

The average yields of the different crops on cropped and on fallowed land for the 36-year period are given (table 4).

TABLE 4.—*Average yields in bushels of crops grown on fallowed land and on cropped land, Colby (Kans.), 1915–50*

Crop	Acre yields		Crop	Acre yields	
	Fallowed	Cropped		Fallowed	Cropped
Winter wheat	19. 6	8. 8	Milo	26. 0	12. 1
Spring wheat	7. 8	5. 3	Kafir	20. 1	7. 9
Oats	26. 0	15. 3	Feterita		[2] 9. 7
Barley	26. 8	15. 0	Coes sorghum		[3] 7. 9
Corn	22. 7	12. 6	Early Sumac sorgo	[4] 19. 2	9. 6
Beans		[1] 3. 0			

[1] 21 years, 1920–50.

[2] 19 years, 1917–45.

[3] 5 years, 1946–50.

[4] 10 years, 1941–50.

Winter Wheat

Winter wheat is the most important crop of the region. Reports of the Kansas State Board of Agriculture show that, in the 37 years covered by this study, Thomas County alone produced approximately 90 million bushels of wheat. More than half of the plots in these experiments were accordingly devoted to winter wheat.

The group of rotations started in 1914 had 30 plots of winter wheat on fallow, mostly in rotation; 2 plots of winter wheat continuously cropped by different tillage methods; 1 plot after corn in 80-inch rows; and 1 plot on green-manured land. About 1920 this group of rotations was expanded to include rotations of wheat after corn and milo in the regular 40-inch row spacing, and more plots of wheat after wheat or some other small grain. In 1932 the work was further expanded to provide: (1) Information on the effects of different implements and times of commencing tillage on yields of wheat grown each year; (2) a more comprehensive test of methods of fallowing; and (3) a group of plots on which winter wheat was seeded in standing cornstalks. Additional work was started in 1939 when interest in runoff-prevention practices made it desirable to study that problem.

Average yields for the 31 years 1920–50 are shown (fig. 4). The annual yields by methods are given (appendix table 26).

Only 1 of the 8 treatments in which wheat followed a small-grain crop was significantly different from the others. This was the plot continuously "stubbled-in" without cultivation. None of the other 7 treatments varied as much as 1 bushel from their general yield average. There are, however, items of interest not shown in the average results but discussed in the following paragraphs.

Wheat was grown after barley and after wheat under two comparable tillage treatments. Where the land was plowed, yields were equal. Where the land was listed, there was a small difference in favor of wheatland. This is attributed to the greater growth of volunteer plants on listed land. Volunteer barley competes with wheat for

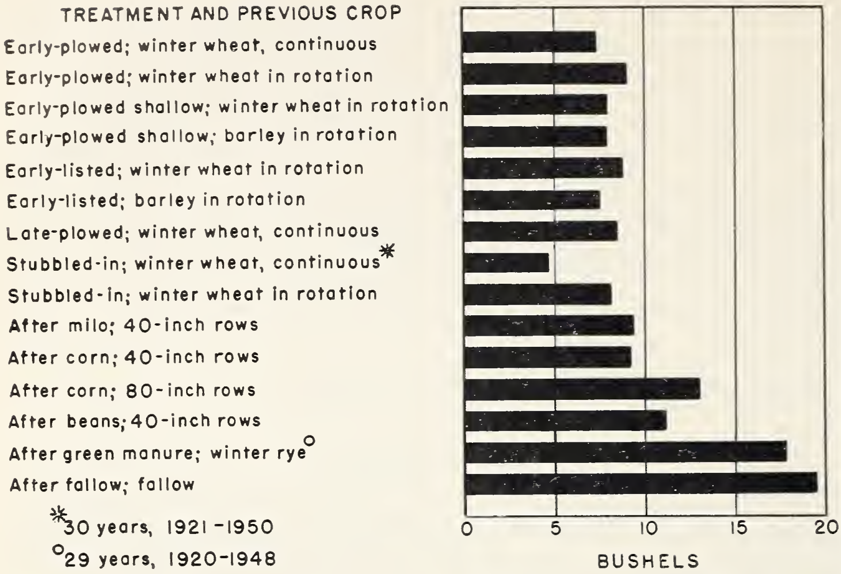

FIGURE 4.—Average acre yields of winter wheat grown under different tillage methods and sequences at Colby (Kans.) for the 31 years, 1920–50.

moisture and plant food in the fall, weakening the plants and reducing the stand, and then dies during the winter. Usually volunteer wheat was not damaging, as the volunteer plants generally survived the winter and were as productive as the seeded plants.

In the group of plots shown (fig. 4), late-shallow-plowed continuous wheat produced a higher average yield than early-fall-plowed continuous wheat.

Wheat in one rotation was seeded without prior cultivation into the stubble of wheat grown on fall-plowed wheatland. This offered a direct comparison between plowing the wheat stubble and drilling without cultivation. The average difference in yield in favor of plowing was only 0.7 bushel. Annual yields differed greatly. There were 5 years in which plowing was much the better, and 3 in which stubbling-in was outstandingly superior. Land where wheat was drilled into wheat stubble did not contain as much moisture at seeding time as did wheat on plowed land, but in many years the snow caught by the standing stubble made up for this deficiency. The standing stubble also protected the crop from injury by soil blowing. In very wet years, however, wheat on stubble was likely to be poorer in color and lower in vigor than wheat on plowed land.

Wheat stubbled-in on the same land continuously produced a much lower yield than did wheat receiving other treatments. During the first 10 years (1921–30), the yield was only about 7.7 bushels, while the average yield of stubbled-in wheat after wheat in a rotation was 10.2 bushels. By the end of the 10 years, the plot had become so foul with grass and grassy type weeds that it was difficult to obtain a stand. It was plowed in the fall of 1930 to kill the grass.

The 10-year period (1931–40) was extremely dry. There was no trouble from grass on the continuously stubbled-in wheat plot during this period. It is probable that the grass would have died even though the plot had not been plowed in the fall of 1930, as the long drought killed grass in pastures on the station and elsewhere in the area. During this 10-year period of frequent wheat failure, the average yield of wheat continuously stubbled-in and the plots of stubbled-in wheat rotation was almost exactly equal—1.9 and 2.0 bushels to the acre, respectively.

The 10-year period (1941–50) was favorable to wheat, although one crop was destroyed by hail; but this period was also favorable to grass in the continuously stubbled-in plot. The average yield of this plot was less than 3.8 bushels to the acre, as compared with 10.5 bushels for stubbled-in wheat after wheat in a rotation.

Growing wheat without cultivation did not affect the fertility or the capacity of the soil to absorb and hold water. Its weakness was that it permitted a gradual buildup of grasses that eventually made wheat production by the method practically impossible.

Yields of wheat after corn and milo in 40-inch rows were approximately equal (fig. 4) and little higher than those of wheat after small grain. This would appear to indicate that milo provides as good a seedbed as corn, but this has not usually been true. In years when a good milo crop was produced, it used moisture until frost; and it tended to exhaust the supply in both the surface soil and subsoil. Wheat following it was able to produce good yields only in years of unusually abundant precipitation. Favorable average results following milo were due chiefly to years in which milo stands were poor and the crop was unable to use all the available moisture, amounting to a partial fallow. Under modern production methods, where milo is harvested with a combine, following it with wheat is usually impractical because of the lateness of the milo harvest. The only bad effect of milo on wheat noted was its late fall use of moisture.

Corn did not generally grow as late in the fall as milo, and it often left moisture available to wheat in the lower depths of soil. The seedbed was usually too dry for prompt wheat germination, and the fall condition of wheat on corn ground was generally poor. Comparatively high yields following corn were obtained when precipitation after seeding was above average, and wheat roots were able to penetrate the soil deeply and make use of moisture left in the lower depths by corn. Under less favorable conditions, wheat roots were unable to remove this moisture. Corn is usually harvested later in the season than is desirable for sowing wheat. If wheat seeding is done at the optimum time, the crop must be drilled between the rows of standing corn. This practice is not well suited to the use of modern production machinery, and cornland is now generally used for spring-sown crops rather than wheat.

A comparison of first- and second-year wheat yields after corn in 2 rotations—one with 2 years of wheat after corn, and the other with 3 years of wheat after corn—showed that the average yield for the second year of wheat after corn in the 2 rotations was only 0.4 bushel lower than the yield for the first year of wheat after corn. This does not mean that the annual yields were approximately equal. There were a few years in which wheat after corn was outstandingly good and about an equal number in which the second crop after corn was much the better.

A comparison between wheat on land where the corn stover was harvested, and on land where wheat was seeded with a 1-horse drill between rows of corn that was later husked in the field and the stalks left standing, is afforded by data presented (appendix table 26). The binder-harvested method was represented by 2 plots, and the field-husked method by a group of 9 plots. During the period 1932–50, the wheat after binder-harvested corn produced an average yield of 7.7 bushels to the acre; and that of wheat planted in standing cornstalks, 8.6 bushels. In most years there was little difference, but in 2 years (1932 and 1941), the protection afforded by the stalks meant the difference between a better-than-average yield and virtual failure.

Wheat following corn grown in 80-inch rows produced a yield 3.9 bushels per acre higher than after corn in 40-inch rows. An appreciable quantity of moisture was left by these wider spaced rows and they constituted a partial fallow. The value of the method, however, depends on the effect on corn as well as on wheat. The yield of corn was reduced about 5.5 bushels to the acre. Wide-spaced corn did not provide insurance against failure, as a yield was obtained in only 1 year in which wheat on 40-inch corn spacing failed.

Wheat on beanland produced a yield 1.9 bushels higher than on comparable cornland. Beans leave in the soil an appreciable quantity of moisture that is available to a succeeding wheat crop. Beans also leave a surface very susceptible to soil blowing, and in some years the stand of wheat was reduced by soil movement. In years when wheat on beanland was not hurt by soil blowing, the yield was comparatively high. Even if beans were a well-adapted crop, the dangerous practice of following them with wheat would be open to question. As discussed later, beans are not adapted to occupy more than a minor place in any cropping system.

The yield on land where a green-manure crop of winter rye had been plowed under was higher than on land where any method of annual cropping had been practiced but lower than on fallowed land. During the 33 years (1915–47) that this work was carried on, the average yield of wheat on green-manured land was 18.1 bushels to the acre, as compared with 20.1 bushels on fallow. The relative behavior in any year seemed to depend on how much the rye depleted soil moisture before being turned under. Any beneficial effect of green manure was more than offset by the moisture required to produce it. Any cumulative change in the soil resulting from plowing under a green-manure crop was not reflected in wheat yields either during the 33 years in which green manure was plowed under, or in the 3 succeeding years in which fallow was substituted.

Average yields of wheat on fallow were practically double those on the best methods of annual cropping. In all except 9 of the 36 years, 1915–50, the yield on fallow was higher than on any method of annual cropping. The average yield on fallowed land was more than double the average yield on cropped land in more than half of the years. In some other years, the yield was much higher than (but not double) that on cropped land. In 6 of the unfavorable years, good yields were produced on fallow when wheat on cropped land was a near failure. However, in 2 years in which fallow exceeded all other methods in yield, the yield on fallowed land was less than 10 bushels to the acre.

Of the 9 years in which one or more methods of annual cropping equaled or exceeded fallow in yield, 5 were years in which all methods failed. Of these 5 years, 2 were years in which yields on both cropped land and fallow were below 5 bushels to the acre. In one of the other 2 years (1923), fallow was the lowest yielding method because of a low winter survival of wheat and more severe rust injury. In the exceptionally favorable year of 1942, wheat on fallow lodged; and although it still produced a good yield, its yield was exceeded by that of several of the annually cropped methods.

In all years in which wheat on fallow failed or returned low yields, the quantity of water in the soil at seeding time was not enough to wet the soil to a depth of more than 3 feet. The greatest average advantage for fallow was in the wet years. In average or good years, fallow proved more effective in increasing production than in preventing failure.

An additional advantage of fallow was shown in 1949 when hail before harvest injured the crop. The wheat on cropped land was severely damaged, but the heavier straw growth on fallowed land was not broken so badly and most of the heads could still be combine-harvested. The plots in that year were not harvested individually, but by groups. The average yield for some of the principal methods were: Fallow, 20 bushels; plowed plots, 7 bushels; and cornland, 2 bushels. Other methods were practically complete failures.

Results of Tillage Experiments

Frequency of Plowing

A series of rotations was started in the fall of 1931, wherein wheat was grown on land plowed every year, every second year, every third year, every fourth year, and every fifth year. The purpose of this experiment was to determine to what extent the expensive practice of plowing could be dispensed with, without serious reduction in yield. In the years when the land was not plowed, the tillage given depended on the amount of weed or volunteer-wheat growth after harvest. Where the stubble was clean and the ground not too hard, wheat was drilled without previous tillage. In other years, the stubble was one-wayed or undercut with subsurface sweeps. In the 19 years (1932–50), the plots not plowed were stubbled-in 8 years, one-wayed 7 years, and worked with sweeps 4 years.

Yields for the different treatments are given in detail (appendix table 27) and summarized (table 5). Land plowed every year produced the lowest average yield. Plowing every year after harvest apparently leaves the soil too loose for best results. Land plowed after a year of stubbling-in or shallow cultivation produced the highest average yield. In every instance, average yields of shallow-cultivated plots the first year after plowing were lower than in any subsequent year and about equal to yields on land plowed every year.

TABLE 5.—*Average acre yields in bushels of winter wheat on rotation plots, plowed at different intervals, and stubbled-in or shallow-cultivated when not plowed, Colby (Kans.), 1932–50*

Plots plowed every—	Average yields for plowed years	Average yields for stubbling-in or shallow cultivation following plowing [1]				Total average yield
		1st year	2d year	3d year	4th year	
Year	7.9					7.9
2d year	12.5	7.4				10.0
3d year	11.0	9.1	9.7			9.9
4th year	11.6	8.0	9.2	9.4		9.6
5th year	10.3	7.9	10.1	9.1	8.8	9.2

[1] Stubbled-in, 8 years; one-wayed, 7 years; subsurface-cultivated, 4 years.

Yields on land plowed after a year of stubbling-in or shallow cultivation were not regularly higher than on land more than a year removed from plowing. The average difference in favor of plowing was the result of much higher yields in a few years with very wet springs when wheat in the stubble of shallow-cultivated land evidently suffered from a nutrient deficiency.

The results indicate that benefit from occasional plowing is partly canceled by reduced yields the year following the plowed year, and that frequent plowing is not necessary or advisable.

Tillage Implements and Practices

Different tillage tools were used after harvest to prepare stubble ground for the next crop of wheat. The tools used were the lister, the disk plow, the one-way disk plow (hereinafter called the one-way), and the moldboard plow (hereinafter called the plow). One-waying and moldboard plowing were used at 2 depths—shallow (3 to 5 inches) and deep (about 7 inches).

The early tillage work was carried out as soon as practicable after harvest, usually in July. In one set of 6 plots (see fig. 2, "W–W Seedbed (continuous)"), the different tillage operations were carried out each year on the same plots. In another set (see fig. 2, "W–W Seedbed (alternate)"), these same 6 tillage operations and 4 additional ones were alternated with uniform preparation. For this alternate-methods set, 20 plots were used, so that 1 crop under tillage variables and 1 on uniformly prepared land could be produced each year. Tillage in the uniform year was the same as that given the unplowed plots in the frequency-of-plowing experiments. Yields are presented (appendix table 28) and summarized graphically (fig. 5).

Where the ground was tilled by the same methods every year, the only treatments materially different from the others were the two moldboard-plowed plots, which were approximately 1⅔ bushels lower in yield. In the alternate-methods block, where the ground was moldboard-plowed following a crop grown on uniformly prepared shallow-tilled land, there was no reduction in yield. The average yields from

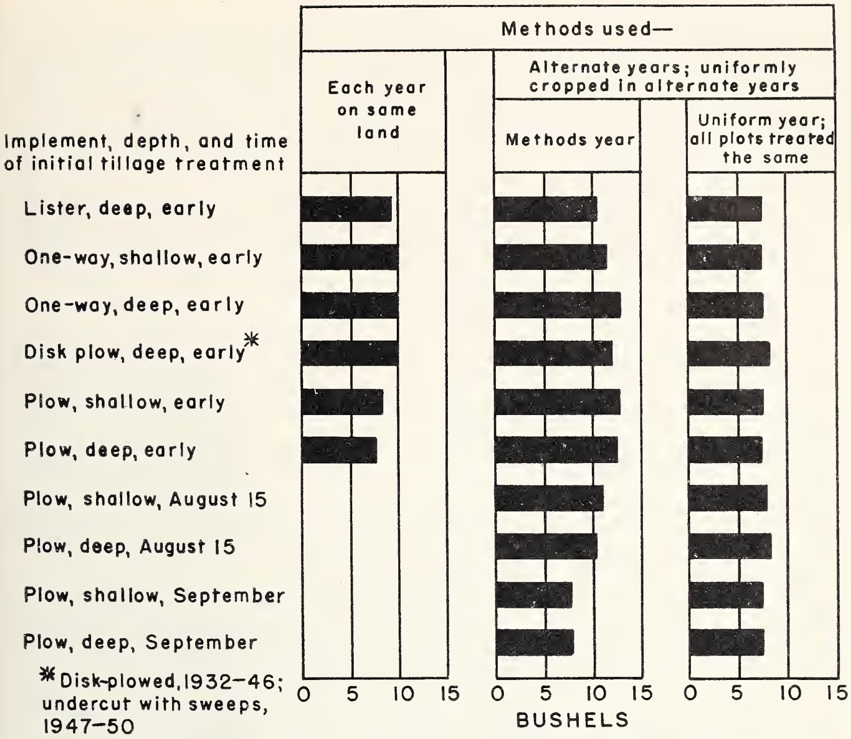

FIGURE 5.—Average acre yields (bushels) of continuous winter wheat on land cultivated by different methods, Colby (Kans.), 1932–50.

the 6 early methods ranged from 10.5 bushels on listing to 12.9 bushels on deep one-waying. The only early method materially lower than the others was listing. A comparison of time and depth of plowing was also included in the alternate methods. For the 19-year period, the yields averaged 12.2 bushels on July plowing, 10.7 on August 15 plowing, and 8.1 on September 15 plowing. In this group there were appreciable differences due to time of plowing, but not to depth of plowing.

That difference between methods in the alternate block were real and not the result of location is evidenced by the behavior of crops on the same plots in the uniform year, when the extreme difference between plots was only 0.9 bushel. The average for the plots when they were treated uniformly was 7.8 bushels. This is 2.7 bushels lower than on the listing, which was the lowest of the other methods, and nearly 5 bushels less than on the average of plowing and one-waying. The difference existed chiefly in some of the high-yielding years when the spring was very wet. In those years the wheat in the stubble was rather yellowish and spindly because the crop residue interfered with obtaining the necessary plant food.

No tillage tool or method used in these experiments proved vastly superior to the other tillage tools or methods. Not enough moisture was received between harvest and seeding in most years to permit much difference in moisture storage under different methods.

In some years early plowing had more moisture in the seedbed, and wheat got a better start than on late plowing. If conditions were favorable the following spring, it made a better yield. A shortage of moisture the following spring often resulted in a lower yield, because there was not enough moisture available to sustain the heavier growth until maturity. In such years methods giving wheat a slower start usually returned higher yields. Stubble and other crop residues on the surface have sometimes caught enough snow and afforded enough protection for the young plants to make up for the poor start in the fall. None of the methods has been a guarantee against failure.

Packing After Plowing

An experiment was started in 1932 to test the value of a packer used immediately after plowing on land plowed early to a depth of about 7 inches. Two plots alternately packed and not packed were used for this experiment. Packing was done with a Campbell type subsurface packer which consists of a number of wheels 12 inches in diameter with fairly sharp, diamond-shaped rims about an inch thick. These wheels were spaced about 5 inches apart on a shaft. They pack the soil, but leave the surface somewhat rough and cloddy. The detailed results are presented (appendix table 29).

The average difference in yield was only 0.4 bushel in favor of the packed plot, a difference too small to have any significance. In 16 of the 19 years, packing or the lack of it was not a determining factor in yield. In the 3 years when there were considerable differences, they seemed to be the result of stand. Two of these years were in favor of the packed plot, one because of better emergence, the other because part of the emerged plants in the looser unpacked land were buried by heavy fall rains. In 1 year the unpacked plot had a better stand and produced a much higher yield.

There are special conditions under which packing may be advisable. Fall plowing which has turned up mellow and fine resists blowing better if packed with the type of packer discussed here. Where there is considerable crop residue on the surface, packing facilitates penetration of the disks of a drill when seeding.

Burning Winter-Wheat Stubble

Considerable winter-wheat stubble has been burned in this section, either intentionally or accidentally. Sometimes farmers have burned to get rid of a heavy crop of straw or weeds so that preparation for the next crop would be easier. Accidental fires occur frequently, especially during hot, windy weather at harvesttime. These fires have been started by locomotives, by exhausts from tractors or other motors, by carelessly tossed matches or cigarettes, and by other means. In some years thousands of acres of ripe wheat have been destroyed. Burning either before or after harvest has resulted in the loss of stubble and straw on the field, and it has frequently created a community blow hazard. The absence of residues on the surface makes the soil susceptible to blowing. Burning has long been recognized as a bad practice by those interested in keeping the soil from blowing and in preserving its productivity.

Two 3-year rotations and 1 check rotation were started in 1932 to test the effect of burning. The rotations were fallow, wheat, fallow; and the heavy straw of the wheat on fallow was burned. Thus, each plot in the rotation was burned once in 3 years.

The methods and the yields resulting from their use are given in table 29 and summarized as follows:

	Bushels
Stubble burned and plot one-wayed immediately at harvest	7.9
Stubble burned just before seeding; no cultivation	9.5
Stubble not burned; wheat stubbled-in or following shallow cultivation	8.1

The plot burned immediately after harvest and the unburned plot produced almost identical yields. The stubble burned at seeding produced a higher yield, but it is believed that the difference was due entirely to location. Figure 2 shows that the rotation where burning was done just before seeding (121–2) was located in one series, and the unburned rotation (568) and the one burned immediately at harvest (121–1) in another. This other series proved to be lower in productivity although there were no surface indications that this was true. In these particular rotations, yields on fallowed land, where the land was prepared uniformly, varied as much and in the same direction as in the treatment year.

As can be seen from the annual yields, there was no depressing effect of burning stubble evident in these rotations. This is to be expected, since differences in organic matter, resulting from destruction or reduction of stubble could not be expected to become evident where burning once every 3 years was carried on only 19 years.

Experiments With Winter Wheat on Fallow

Methods of Fallow for Winter Wheat

Methods of fallow for winter wheat have been studied in two sets of experiments, one of which was started when the experiments were begun, the other in 1931. In the following discussion, these are designated, respectively, as *Methods-of-Fallow Experiment No. 1* and *Methods-of-Fallow Experiment No. 2.* The first experiment was designed chiefly to determine when cultivation for fallow should start; the second, to test other implements in comparison with the plow and lister. In both experiments weeds were controlled from the time of the first tillage operation until seeding, by working the ground with some surface tillage tool as often as necessary.

The implements used for the surface cultivation were the springtooth harrow, duckfoot, subsurface sweeps, and the rotary rod weeder; also on some occasions, the one-way, run as shallow as it could be operated effectively. The number of surface-tillage operations varied with the time tillage was started, with the implement used for the first tillage, and with the season. They ranged from 0 to 7. During the early years the listed plots were leveled with a lister cultivator, but in later years the ridges were gradually leveled by working with surface-tillage tools.

Method-of-Fallow Experiment No. 1 was started in 1915, but the yields used for comparison are for the period 1922–50. Prior to 1921, differentiation between some of the methods was not as well established as it became later. This experiment was conducted on land alternately fallowed and cropped. Average yields from the five treatments are shown (fig. 6). The detailed annual yields are given (appendix table 30).

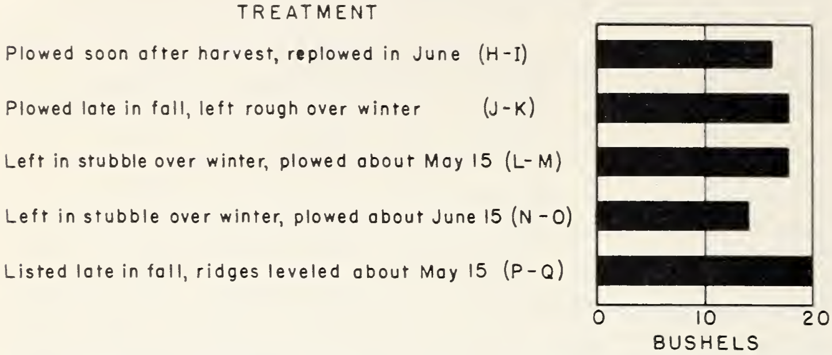

Figure 6.—Yields of winter wheat on fallow prepared by different methods, Colby (Kans.), 1922–50.

The first method represented the longest and most intensive fallow period. The land was plowed after wheat harvest at an average date of July 25, kept free from weeds through the fall and spring, replowed in June, and given the surface cultivation needed to keep it free from weeds until seeding. This usually required an average of more than 4 surface cultivations in addition to the 2 plowings. Seeding was usually done shortly after the middle of September, making the fallow period about 14 months long. The average yield from this method was 16.6 bushels to the acre and was lower than for late fall or May preparation. The chief drawbacks to the method were that the surface was generally smooth during the winter and did not catch snow, and that the soil tended to pack before the June plowing so that water could not be absorbed rapidly. The unduly long fallow period increased the cost of maintaining fallow and reduced the yield.

The two late-fall-prepared plots were either plowed or listed on the average date of October 30. This reduced the fallow period to 11 months and the average number of surface-tillage operations to 4. The land was left rough over winter, and snow accumulations evidently compensated for loss of moisture after harvest. Listed land produced a higher yield than fall-plowed land and was a little more resistant to soil blowing, but was not immune to it. Fall listing was a difficult operation when the soil was dry.

May plowing was the most efficient method under test. The fallow period was reduced to 4 months and the number of surface cultivations to less than 3. The method had other advantages. The stubble prevented wind erosion during the winter and spring. Some moisture was lost by weeds and volunteer growth during the fall and spring, but this was compensated for because the stubble caught and held snow, checked runoff, and lessened evaporation by shading the ground. All things considered, it was a more satisfactory method of fallowing than fall listing. A plot that has been May-plowed for fallow and the wheat crop grown by this method are shown (fig. 7).

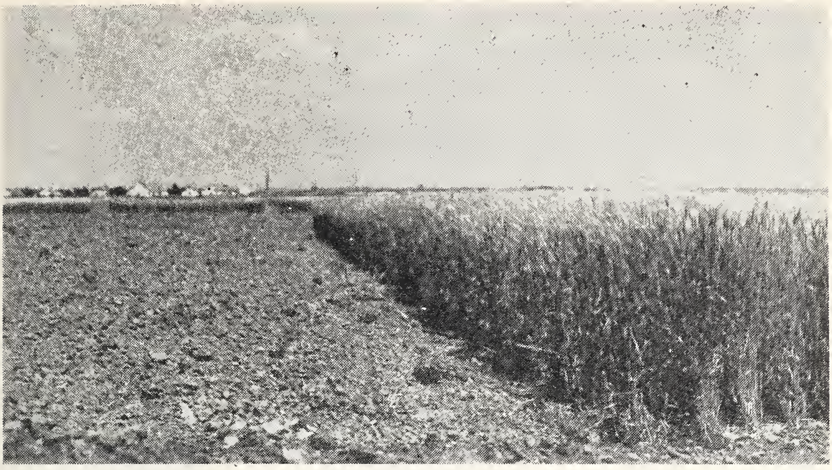

FIGURE 7.—Winter wheat on May-plowed fallow (right) and land being fallowed by that method (left) at the Colby Branch Station.

Plowing in June reduced the fallow period to 3 months and the number of surface cultivations to 2. The reduced cost of operation, however, did not compensate for the difference in average yield, which was 3.7 bushels below that on May plowing. Weeds and volunteer wheat had not used much moisture by the middle of May, but were using water rapidly by mid-June. May plowing is done in advance of the wet period in late May and early June. As June plowing is done after this period, much of its precipitation is lost. The result is a lower soil-moisture content and a seedbed that is undesirably loose at seeding time unless summer precipitation is above average.

Methods-of-fallow Experiment No. 2 was started in 1931 (first yields in 1932), to compare other tillage tools with the plow and lister in fallowing for wheat. In this experiment winter-wheat stubble on land to be fallowed was left undisturbed in the fall. Instead of alternating wheat with fallow, 2 crops of wheat were grown following the fallow, making 3-year rotations of fallow, wheat, wheat. The comparisons included fallowing with the duckfoot or sweeps only, fallowing with the one-way only, plowing and listing about the middle of May with and without previous spring tillage, plowing about the middle of June with and without previous spring tillage, and double listing.

Yields obtained in this study are presented (fig. 8) and are given in detail (appendix table 31). The average yield of wheat on fallow, excluding the June-plowed plots, was 19.4 bushels for the 19-year period. Two of the May-plowed plots were duplicates. One of these was the third from the north and the other was the third from the south of the block of 10 plots. One of these averaged 20.2 bushels and the other averaged 19.0 bushels to the acre. They represent the highest and the lowest average yield in the series, with the exception of the rotation where the duckfoot or sweeps were used and the 2 plots plowed in June.

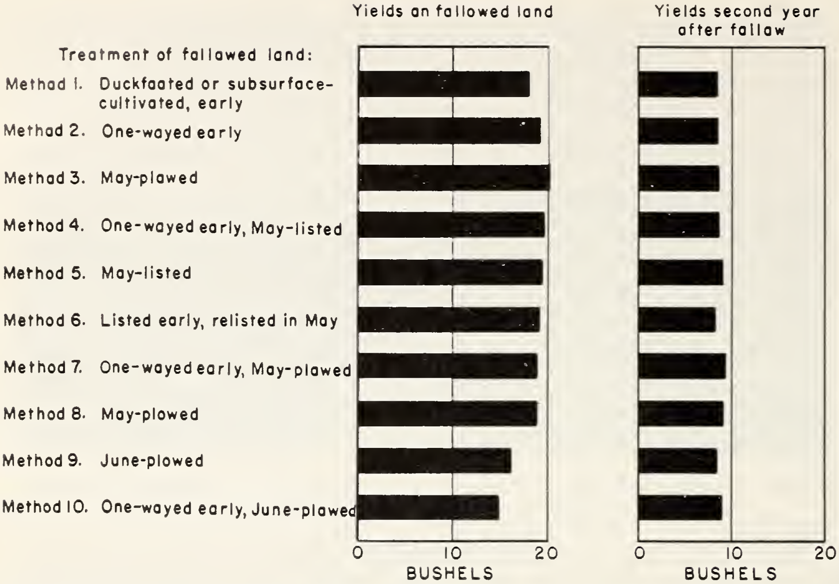

FIGURE 8.—Yields of winter wheat in 3-year rotations on land fallowed by different methods, and yields on the same plots the second year after fallow, Colby (Kans.) 1932–50.

The six plots (fig. 8), where early work is indicated were given their initial tillage treatment when weeds and volunteer wheat were beginning to grow appreciably, usually the latter part of April.

The plots where the duckfoot or sweeps were used were worked with 10- to 12-inch shovels the first 14 years. From 1946–50, inclusive, 30-inch subsurface sweeps, which undercut the stubble without ridging the ground appreciably, were used. Some difficulty was experienced in working heavy stubble with the shovels or sweeps. The wheat on the plots worked with the duckfoot or sweeps averaged 18.4 bushels. The plot maintained with a one-way averaged 19.5 bushels. The one-way was more effective in controlling weeds. It did not leave as much of the crop residue on the surface, but there was not much difference in this respect by wheat-seeding time. The surface of the one-wayed ground was somewhat finer and smoother, hence more erosible.

The two plots one-wayed early and then plowed or listed about May 15 were free of weeds and were usually wetter than those given their initial tillage at that time. This had no appreciable effect, as average yields were nearly the same. The plot listed early and relisted in May produced a yield about equal to that of the plot listed in May.

The plot one-wayed early and plowed about June 15 and the plot not one-wayed prior to the June 15 plowing were the lowest yielding methods in this experiment, averaging 4.0 and 2.4 bushels less, respectively, than the May-plowed plot located nearest to it. The plot one-wayed early was usually free of weeds and the plow layer wet at plowing time. The plot not one-wayed was usually very weedy by June 15, and in some years there was considerable volunteer wheat, some of which had headed. It turned up much drier than the early-one-wayed plot, but it produced an average yield 1.6 bushels higher. Furthermore, it outyielded the early-one-wayed plot in 8 years, and equaled it in 1 of the 14 years in which yields were obtained. The results indicated that yields are likely to be reduced sharply by delaying plowing for fallow until June 15, even though weeds are controlled by early cultivation.

There was little difference in the effect of the several types of implements on the yields of wheat. Comparable one-wayed, listed, and plowed plots produced average yields within a fraction of a bushel of each other. The plot where subsurface sweeps were used exclusively was more than a bushel per acre below the others in yield, but this difference could probably have been reduced by occasional tillage with an implement more capable of controlling weeds. Average yields, however, do not tell the whole story. Land worked with tools that leave most of the crop residues in the surface layer is more resistant to wind and water erosion than plowed land. Care must be exercised in the use of the one-way to avoid pulverizing the loose surface so finely that it will blow easily and resist water penetration. The one-way alone was used successfully in these experiments, but it would be more satisfactory to use other surface-tillage tools, such as the duckfoot or sweeps, in combination with the one-way.

The average number of surface workings required over the 19-year period was 4 to 5 for the duckfoot or sweeps, 4 for the one-waying, 3 for the May plowing and listing, and 2 for the June plowing.

The second crop of wheat after fallow in this experiment (fig. 8 and table 31) was produced with a minimum of seedbed preparation. It was drilled in the stubble in 8 years. The stubble was one-wayed in 7 years and was undercut with the subsurface sweeps in 4 years. The average yield of the second crop of wheat was 8.7 bushels, approximately 45 percent of the average on fallow, other than the June plowed, in this group. Plot yields did not differ significantly.

Fallow Followed by 3 Years of Winter Wheat

Two rotations (566–1 and 566–2) were started in 1931, partly to determine whether there was a material effect from moisture left in the soil by winter wheat grown on fallow, and partly to compare the effects of harvesting with a binder and with a combine. Results are presented (appendix table 32, upper section).

The effects of location, discussed earlier, make it impossible to compare rotations. The higher yields recorded for the combine-harvested plots undoubtedly resulted from more favorable location.

Comparisons within rotations, however, are valid. Yield from the second and the third crops after fallow were practically equal. There were years in which some moisture was left in the soil in the lower depths after the wheat on fallow was harvested. This did not usually help the crop following, as wheat roots did not reach it except when precipitation was sufficient to wet the soil to that depth. This rarely happened, and in most years water left in the lower depths remained there until the soil was wetted to that depth during the next fallow season. The next crop on fallowed land might or might not remove it.

So little moisture was stored by fallow in a single year in the thirties, that a 4-year rotation was started (first crop on 2-year fallow in 1939) in which the land was fallowed 2 years and then planted to wheat 2 years. Plowing was done about the middle of May in the first year of the fallow period, and the land was given the same tillage as on other fallow plots until fall. Late in the fall the ground was ridged and roughened with a chisel to keep it from blowing. The second year the ground was worked with surface-tillage tools. The second crop after fallow was either drilled in the stubble or the stubble was one-wayed or undercut with subsurface sweeps. Results are shown (appendix table 32).

The average yield of wheat for the 12-year period (table 32) was 22.5 bushels after 2 years of fallow, and 12.2 bushels for the second crop after 2 years of fallow. The average yield of wheat for all plots after 1 year of fallow for the same period was 21.6 bushels.

Two-year fallow was not effective in reducing the number of failures. In years when the surface soil was very dry, it was as subject as other methods to poor stands and winterkilling. It showed to best advantage in years when moderate but not high yields were obtained on 1-year fallow.

These results make it appear that it is not profitable to fallow ground more than 1 year at a time, unless the moisture of the soil is very low and the conditions at seeding time are unfavorable for prompt fall germination. In 4 of the 12 years that the rotation was in operation, the 1-year fallow plots averaged more than the 2-year plots. There were very wet years in which more of the wheat on the 2-year-fallow plots lodged.

Basin Listing and Diking for Winter Wheat

Three 3-year rotations consisting of fallow followed by 2 crops of winter wheat were started in 1939 to compare ordinary listing, basin listing, and bordering with a dike to prevent runoff (appendix table 32). The use of a dike is not a practical method, but it was included to determine whether preventing all runoff would result in larger yields.

The plots being fallowed were prepared as follows: The plot prepared with an ordinary lister was fall listed and then worked down the following spring; the basin-listed plot was fall basin listed, and the ridges were split with a basin lister when spring tillage was needed. This maintained the basins until the middle of June or later, when the ridges were leveled to prepare a seedbed. The diked plot was May plowed. Average yields for the 12-year period were 20.5 bushels to the acre on ordinary listing, 20.2 bushels on basin listing, and 21.5 bushels on the diked land. The dike sometimes held too much water on the land, causing the wheat on fallow to lodge more severely than on the listed rotations.

The land for the second crop after wheat was handled as follows: The listing and basin listing were completed as soon as practicable after harvest. Ridges were leveled the latter part of August, preferably after a good rain. The diked plot was cultivated with a one-way or sweeps if cultivation was required. Otherwise, the wheat was planted in undisturbed stubble. Average 12-year yields for the different methods were 15.0 bushels to the acre on ordinary listing, 14.7 bushels on basin listing, and 11.9 bushels on the diked land. The reduction in yield on the diked plot was about the same as that for the similarly cultivated uniform plots (fig. 5), discussed previously.

A single plot of continuous wheat (table 32, bottom line) was grown adjacent to the three 3-year rotations, to determine whether preventing runoff would make fallow unnecessary. The land was handled the same as the second crop of wheat on the diked 3-year rotation. The average yield, 12.1 bushels to the acre, was almost identical with that of second-year wheat on diked land. Like all wheat planted on land where considerable residue remained on the surface, a nutrient deficiency was shown in cold wet springs. It is probable that this could have been at least partly corrected by nitrogen fertilizer.

The results of this study provide no evidence that impounding water with the basin lister or with dikes has improved yields of wheat.

Spring Wheat

In these experiments spring wheat has been grown continuously on fall and on spring plowing, in rotations, on fall and on spring plowing after oats and after corn; on disked corn ground; and on fallow. The average yields for the 36-year period are shown (table 6).

TABLE 6.—*Average yields of spring wheat under different sequences and tillage practices, Colby (Kans.), 1915–50*

Tillage treatment and previous crop	Plots averaged	Acre yield
	Number	*Bushels*
Spring-plowed:		
Spring wheat	1	[1] 5.0
Oats	1	[1] 5.4
Corn	1	[1] 5.6
Early-fall-plowed:		
Spring wheat	1	5.4
Oats	2	[1] 5.5
Late-fall-plowed:		
Corn	1	[1] 4.5
Disked:		
Corn	1	5.4
Fallow	2	[2] 7.8

[1] 32-year average.
[2] 1 plot after 1946.

All yields of spring wheat were low in comparison with those of other crops. This indicates that spring wheat is not adapted to this section of Kansas. It is the only crop tried in these experiments that did not give a creditable yield on fallow.

The average yield on fallow for the 36-year period was 7.8 bushels to the acre. This is less than half the average yield of winter wheat on fallow. The highest average yield of spring wheat on cropped land was 2.2 bushels lower than the lowest yielding similar method for winter wheat. Spring wheat produced as much as 20 bushels to the acre only once on cropped land and only twice on fallow. These results do not justify growing spring wheat in this area, even as an emergency crop when winter wheat has failed to survive the winter.

Oats

In these experiments oats have been grown on land continuously cropped to oats, and in rotations. The yields for the 36-year period are shown (appendix table 33). Oats grown on continuously cropped land averaged approximately 16.5 bushels to the acre. Yields in rotations averaged 15.3 bushels after small grains, 13.3 bushels after corn on spring plowing, and 15.4 bushels on disked corn ground. The 2 plots on fallowed land averaged 25.4 bushels.

The crop does not respond as well to fallow as do winter wheat and barley, chiefly because it is less tolerant to high temperatures and drying winds that often prevail during the ripening period. However, complete failures were no more frequent with oats than with commonly grown crops. This has been especially true since 1929 when a better adapted variety, Kanota, was substituted for Kherson which had been grown previously. Since Kanota has been used, the pounds of oats produced per acre has more nearly approached that of barley.

Oats are popular as a feed grain. Farmers like them especially for feeding to young growing animals, and often sow small acreages for this purpose. In some wet years, very high yields have been obtained both on cropland and on fallow. They remain a minor crop, however, because the yield in pounds per acre is lower than that of barley. Difficulty is experienced in harvesting oats with modern machinery, as they lodge readily when mature and are even more subject than barley to grasshopper damage at harvesttime. The loss from shattering caused by grasshoppers cutting off spikelets is often heavy.

Oats are usually grown on row-crop ground as it requires a minimum of preparation. They can, however, be successfully grown after oats or some other small grain, providing weeds are controlled. This can best be accomplished by turning the ground over with a moldboard plow and burying the weed seeds so they cannot come up until the oats have a good start. Weed control cannot usually be accomplished satisfactorily with a one-way or other surface tillage tools.

Although fallow can be used more profitably for other crops, it is a satisfactory practice for growing oats. The chances of a high yield are much better on fallow than on cropland, and the chances of failure are somewhat smaller.

Barley

Barley has been represented in the experimental work by 8 plots, 3 of them in continuous or alternate cropping to barley and 5 of them following other crops in rotations. The continuously cropped plots and 2 of the rotations were started in 1915. The other rotations were started later to provide additional comparisons. The summarized data are given (table 7) and the detailed data (appendix table 33).

TABLE 7.—*Average yields in bushels of barley under different sequences and tillage practices, Colby (Kans.), 1915–50*

Tillage treatment and previous crop	Average yield for—		
	1915–50	1920–50	1932–50
Spring-plowed:			
Barley	14.9		
Oats	15.9		
Early-fall-plowed:			
Barley	15.2		
Disked:			
Corn	13.6	12.3	9.2
Milo		12.3	
Standing corn stalks			10.3
Fallow	26.8		

Barley after small grain produced an average yield of 15.3 bushels to the acre. Neither the tillage treatment nor the previous grain crop affected the yield appreciably. Barley on disked corn ground from which the stalks had been harvested produced only 13.6 bushels per acre, which is less than the yield following small grain. This is contrary to the general belief. Disked-corn ground is accepted as being a productive as well as an economical method of growing small grains. It has not proved superior to small-grain ground for any of the spring-seeded small-grain crops at Colby.

Rotations started in 1920 made it possible to compare results from disked corn ground with disked milo ground. There was no difference in average yield of barley. Annual differences have usually been small. The only years in which yields following milo were appreciably higher occurred when the preceding crop of milo had a thin stand which left the ground in a partially fallow condition. After 1938, milo was hand-headed and the stalks were left standing. There was only 1 year, 1941, in which the additional snow caught by the milo stalks affected the yield noticeably.

A rotation in which barley was seeded in standing corn stalks was started in 1932. The 19-year average yield was 1.1 bushels higher than on disked corn ground from which the stalks had been harvested. This average difference was due entirely to 2 years (1922 and 1941) when the yield on standing stalks was much the higher. The average for the other 17 years was slightly higher on the harvested plots.

Barley responded strongly to fallow. The average yield of 26.8 bushels to the acre was 1.75 times as great as the yield on small-grain land and nearly double the yield on corn ground. Barley on fallow failed completely only twice in the 36 years. On cropped land 6 complete failures occurred.

During the 36 years, barley produced more pounds of grain to the acre than oats in all tillage and cropping sequences. The margin of difference was much greater on fallowed land than on other preparations.

Northwest Kansas is the principal barley-growing section of the State. For many years barley was the leading feed grain and was exceeded in acreage by winter wheat only. In the 10 years 1941–50, barley, particularly on fallow, produced less grain than milo. Much of the barley acreage has been replaced by milo or other grain sorghums. Spring barley has not yielded so well during the wet period since 1941 as it did in previous wet years. Many farmers started growing winter barley, which for several years produced very high yields. It is subject to winterkilling in this area, however, and stands are usually thinned appreciably in all but the most favorable winters. In 1950 and 1951, winter barley died out almost completely.

Farmers seldom summer-fallow their ground for barley. Most of the barley on this preparation is on land where winter wheat on fallow failed to survive the winter. This is a good practice when it is evident early in the spring that the wheat is too thin to leave for harvest and barley can be seeded in season. Much better results may be expected by seeding the field to barley than to spring wheat.

Barley after small grains or row crops should produce average acre yields about one-half as high as those on fallow. Barley on small-grain-stubble ground may be damaged by weeds unless the land has been plowed and the weed seeds turned under deep enough to delay their emergence until the barley has a good start. Surface working is usually sufficient on row-crop ground.

Corn

Corn was an important crop when rotation studies were started; and it remained second in importance to winter wheat until recent years, when its acreage fell considerably below that of barley and somewhat below that of grain sorghums.

Annual yields of ear corn are given (appendix table 34). Average yields associated with some of the more important practices are grouped (table 8).

Plowing and then surface planting corn on corn ground produced an average yield of only 11.2 bushels to the acre. Corn ground listed at planting, with and without previous shallow tillage, produced yields of 15.6 and 14.9 bushels to the acre, respectively. Not only was the average yield higher on listed land, but the crop was less subject to complete failure (appendix table 34).

Plowed small-grain ground was surface planted, 1915–30. The superiority of listing the continuously cropped plots made it appear likely that a change in planting method might be beneficial on small-grain stubble. After 1930, the plots were plowed as before, but were lister planted. The change in planting method did not cause a measurable change in yield. The relative yield on small-grain ground was a little higher than for the first 16 years, but the same held true on land where there was no change in planting method.

Corn planted with a lister on land that had not been disturbed to lister-planting depth produced a higher yield than corn that was surface planted on plowed land. It made a slower early growth and suffered less damage from hot winds and high temperatures at tasseling time. Such conditions were especially injurious to surface-planted corn when there was a shortage of soil moisture.

Corn planted with a lister on land plowed before planting made a growth similar to that on plowed surface-planted land, and it pro-

TABLE 8.—*Average yield of ear corn under different tillage and planting practices, Colby (Kans.), 1915–50*

Tillage, previous crop, and planting method	Plots	Average yield for—		
		1915–50	1915–30	1931–50
Plowed:				
Corn (continuous)—	*Number*	*Bushels*	*Bushels*	*Bushels*
Surface-planted	2	11. 2	16. 4	7. 0
Small grains—				
Surface-planted	7		16. 0	
Lister-planted	7			7. 9
Listed:				
Corn (continuous)—				
Listed at planting	1	14. 9	20. 0	10. 9
Small grain—				
Listed at planting	1	[1] 14. 4	[2] 18. 5	11. 6
Milo—				
Listed at planting	1	[1] 12. 2	[2] 16. 8	9. 0
Early disked; listed:				
Corn (continuous)—				
Listed at planting	1	15. 6	21. 0	11. 3
Listed:				
Small grain—				
Lister-planted in 80-inch rows	1	9. 7	11. 9	8. 0
Milo—				
Lister-planted in 80-inch rows	1	7. 7	9. 9	6. 0
Fallowed:				
Fallow—				
Surface-planted or listed [3]	1	22. 7	28. 9	17. 7

[1] 34-year average, 1917–50; yield of comparable plot on corn ground for same period, 14.4 bushels.

[2] 14-year average, 1917–30; yield of comparable plot on corn ground for same period, 19.9 bushels.

[3] Surface-planted, 1915–36; lister-planted, 1937–50.

duced a yield little (if any) higher. This is illustrated by the 7 plots on plowed small-grain ground (table 8) that were surface planted 1915–30 and lister planted 1931–50. The yield in relation to other methods was changed very little by the change in planting method.

Disking or other shallow working to kill a crop of weeds before planting increased the average yield by only a fraction of a bushel, but it had other advantages. It provided a better soil condition for listing at planting and reduced the effort necessary to control weeds.

Corn was planted in 80-inch, double-width rows after winter wheat and after milo, to determine whether the additional moisture provided by wide spacing would reduce the hazard of complete failure. It did not accomplish this, however; in no year did the 80-inch spacing produce a crop when 40-inch rows failed. It did exceed the yield of the 40-inch spacing in a few years, with very low yields for both methods. On the average, however, the yield from the regular spacing (40-inch rows) was greater by about 4.6 bushels to the acre—or approximately 50 percent higher—than from corn grown in 80-inch rows.

Stover yields from 80-inch spacing were reduced to a greater extent than were grain yields. This was particularly true in adverse years when stover production was most important. Corn in 80-inch rows appeared to be more susceptible to damage from hot winds, grasshoppers, and hail, than corn in 40-inch rows. This is evidenced by a slightly higher percentage of complete failures and by lower production compared to that of corn in 40-inch rows during such years.

Corn in 80-inch rows did not use all available moisture between the rows. This resulted in higher yields of milo and wheat after corn with 80-inch than with 40-inch row spacing. This partially compensated for the reduced yield of ear corn and stover.

There are only a few clearcut cases of differences in corn yield due to crop sequence (table 8). Yields after corn and after small grain under comparable tillage methods were much the same.

Yields following milo were about 2 bushels to the acre lower than following small grain, in both the 80-inch and 40-inch rows.

Fallow provided a favorable sequence for corn, but the average yield of 22.7 bushels to the acre was less than 50 percent higher than on listed cropland. This is too small a response to make fallowing for corn a desirable practice.

Fallow did not decrease the chance of complete failure. Fallowed corn failed completely in every year when corn on listed cropland failed, and low yields were almost as frequent. Fallowing had one advantage not apparent in the acre yields—it produced larger ears and fewer nubbins than did cropland.

From 1915–36, corn on fallowed land was surface planted. Beginning in 1937, it was lister planted, but the change in method of planting made little or no change in its relative yield.

Corn after barley (appendix table 34) produced a yield slightly lower than after other small grains. This in itself is not significant. Yields of oats and barley were also a little lower on barleyland (appendix table 33). This makes it appear likely that barley, the most productive spring-sown small-grain crop, leaves a seedbed slightly less favorable to following crops than do other spring-sown grains.

A group of 2-year rotations was started in 1931, to compare different methods of handling winter-wheat stubbleland before planting with a lister. The methods and the average yields (1932–50) resulting from their use are shown (table 9). Differences resulting from methods of preparation were small, but fall listing appeared to be superior to spring listing, except for the plot that was left without further tillage until the ridges were split at planting. Weed control was difficult on this method. The ridges were usually green with weeds by planting time, and not all of them were killed by the lister-planting operation.

The decline in corn acreage that has taken place over the last 20 years has resulted from a number of factors. Much of the acreage formerly planted to corn has been fallowed in recent years. The decline was further accentuated by the introduction of adapted, combine type grain sorghums that could be produced efficiently with modern wheat machinery. These sorghums are more productive than corn in most years, especially on fallowed land.

TABLE 9.—*Average yields in bushels of listed corn on winter-wheat stubble prepared by different methods, Colby (Kans.), 1932–50*

Preparation method	Average yield	Preparation method	Average yield
Fall-listed (November):		Spring-listed (April):	
Fall-listed, leveled in spring, planted in same furrow	13. 1	Spring-listed, ridges split in planting	12. 7
Disked after harvest, fall-listed, spring-leveled, planted in same furrow	14. 0	Spring-listed, leveled, ridges split in planting	11. 6
Fall-listed, spring-leveled, ridges split in planting	12. 4	Spring-listed, leveled, planted in same furrows	10. 6
Fall-listed, ridges split in planting	11. 7	Spring-disked or subsurface-tilled, lister-planted	11. 5
		Lister-planted, no previous preparation	11. 3

Milo

Ever since its introduction into Kansas, milo has been grown on a small acreage in this area. It did not become an important crop, however, until early-maturing combine types were developed.

Dwarf Yellow was used in these experiments 1915–37, as it was the most suitable variety then available. The growing season was too short for it to mature before frost regularly. It was harvested with a binder and the grain threshed from the bundles after drying. A short-growing, early-maturing variety that could be harvested with a combine was grown 1938–50.

How the yield of milo has changed in comparison with that of corn through the use of early-maturing varieties can be illustrated by the average yields of milo and corn grown in a rotation of wheat, wheat, milo, corn. During the period 1917–37, the average yield of corn was 12.3 bushels to the acre; that of milo, 10.4 bushels. In the 13 years after 1937, an early-maturing combine-harvested variety of milo was grown; the average yield of corn was 12.1 bushels to the acre, and that of milo was 14.4 bushels. Not only was the relative yield of milo greatly increased, but the quality of the grain was improved and the cost of harvesting greatly reduced.

Although yields were changed by the introduction of new varieties, the relationship between cultural methods remained much the same. Average yields from some of the more important practices are shown (table 10) and annual yields are given (appendix table 35).

Lister planting without previous cultivation produced yields about equal to those of plowing and surface planting. This is in contrast to results with corn, where lister planting was considerably the better.

Early disking in advance of lister planting increased yields nearly 2 bushels to the acre. Tillage well in advance of lister planting is much more important for milo than for corn. Milo is planted considerably later than corn, and weeds on untilled land have a chance to make more headway and waste more moisture.

TABLE 10.—*Average yields of milo under different tillage and planting practices, Colby (Kans.), 1915–50*

Tillage, previous crop, and planting method	Plots	Acre yield, 1915–50
Spring-plowed:		
Milo (continuous)—	*Number*	*Bushels*
Surface-planted	1	11. 9
Fall-plowed:		
Milo (continuous)—		
Surface-planted	1	10. 9
Listed:		
Milo (continuous)—		
Listed at planting	1	10. 7
Disked and listed:		
Milo (continuous)—		
Listed at planting	1	12. 5
Winter wheat:		
Listed at planting	13–23	13. 2
Corn in 80-inch rows—		
Listed at planting	1	13. 6
Fallowed:		
Fallow—		
Surface-planted	3	26. 1

The chief difficulties in milo production are obtaining good stands and having it reach maturity before frost. Stands of lister-planted milo are frequently thinner than on surface planting, emergence is less prompt,and maturity may be later. This is compensated for, at least in part, by less damage during severe drought periods. The average yield of milo was increased by spring disking in advance of lister planting, but the danger of not having the crop mature fully remained the same. Crops following thin stands of milo are benefited to some extent by moisture left in the soil by such stands (see p. 15).

Wheat stubble, because of its ability to catch snow, usually had a higher spring moisture content than land where milo was grown each year. If weeds and volunteer grain were controlled, wheatland usually produced a higher yield. Volunteer wheat and weeds are more troublesome on wheat than on row-crop ground; and if they are not kept under control, the higher spring moisture content may be lost before milo-planting time.

On land where corn had been grown in 80-inch rows, milo produced a yield only about a bushel to the acre higher than after milo in 40-inch rows.

Milo responds well to fallow (fig. 9). The average yield was more than double that on land where a crop had been grown. Fallowing was not a complete protection against failure, however, as milo on fallow failed as frequently as on surface-planted cropland (appendix table 35).

Milo was grown following winter rye plowed under for green manure in 2 rotations. and after peas plowed under for green manure in 1 rotation (table 35). During the 33 years (1915–47) that these rotations were in operation, the average yield was 19.8 bushels to the acre as compared to 25.1 bushels on fallow. The green-manure crops

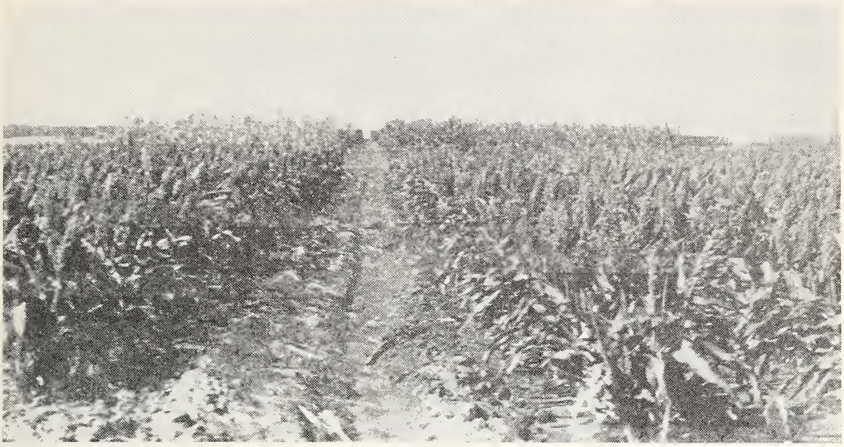

FIGURE 9.—Milo on fallowed land (right) and on cropped land (left) at the Colby Branch Station.

were replaced by fallow in 1948, and the rotations continued in order to test their residual effects. For the 3 years after the change was made, the average yield of the green-manure rotations was 36.9 bushels to the acre, compared with 36.8 in the regular fallow rotations. There was no measurable residual effect on yield; this was to be expected, since there was no response to manure.

No bad effects of continuous milo became evident during the course of this experiment, even after 36 years. Periconia root rot made it necessary to change to a resistant variety, but the change was equally necessary for milo grown in rotations.

Methods of preparing winter-wheat stubbleland for milo were tested over a 16-year period. The methods and the average yields resulting from their use were:

Method No:	*Yields (bushels)*
1—Fall-listed, spring-leveled, lister-planted (3 plots)	14.4
2—Disked after wheat harvest, fall-listed, spring-leveled, lister-planted	15.1
3—Fall-listed, spring-harrowed, lister-planted by splitting ridges	14.0
4—Fall-listed, spring-harrowed, lister-planted in same furrows	12.2
5—Fall-listed, lister-planted by splitting ridges	12.7
6—Spring-listed, surface-planted in lister furrows	11.7
7—Spring-disked, lister-planted	12.8
8—Lister-planted without previous cultivation	11.1

Yields were affected by stand, and also by weed control and consequent moisture conservation. Fall listing appeared to be superior to spring listing provided subsequent tillage was sufficient to control weeds. Methods 1, 2, and 3 fulfilled this requirement. Method 2, where the land was disked soon after wheat harvest, provided the best weed control and produced the highest yield. Under method 4, where the land was fall listed and spring harrowed, and milo was planted by nosing out the same furrows, stands were as good as on the other fall-listed plots; but weed control after planting was difficult, as the planting method did not kill the weeds on the ridges. Fall listing and lister planting by splitting ridges, without intervening spring cultivation (method 5), resulted in poorer stands and a reduced average yield. The ridges were usually weedy and the seedbed drier and more cloddy than on any method other than the one given no cultivation before planting (method 8).

Good stands were obtained where the land was spring listed and the milo surface planted (method 6), but the plot was weedy and the yield no higher than from other methods that did not fully control weeds.

Spring disking in advance of lister planting (method 7) produced a yield 1.7 bushels higher than when the spring disking was omitted (method 8). The difference in favor of cultivation prior to lister planting was about the same as in the continuous-cropping test (table 10).

Kafir

When these experiments were started, kafir was a leading grain and forage sorghum. Three plots of early type dwarf kafir were grown for the entire 36-year period. Two were on continuously cropped land, plowed either in the fall or spring. The third was on land alternately cropped and fallowed. All the plots were surface planted.

Average yields on spring plowing and fall plowing were identical, 7.9 bushels to the acre. Annual yields varied somewhat. The average yield on fallow was 20.1 bushels. Kafir failed to produce grain in 8 of the 36 years on fallow and in 14 years on cropland.

Continuous milo outyielded continuous kafir by 4 bushels on spring plowing and 3 bushels on fall plowing. On comparable fallowed plots, milo averaged 6.1 bushels more than kafir. Even the early type of dwarf kafir used seldom matured fully before frost.

Feterita and Coes Sorghum

Feterita was grown on 4 plots from 1917 to 1945. It was lister-planted each year on the same land. The 29-year average yield was 9.7 bushels. For the same 29 years, continuously listed milo averaged 12.6 bushels. Good stands of feterita were harder to obtain than good stands of milo, but feterita matured earlier than Dwarf Yellow milo—usually before frost. With the advent of the early-maturing combine types of sorghums, feterita production in the area ceased.

Coes sorghum was substituted for feterita on these plots in 1945. Coes is an early-maturing variety grown extensively in recent years over this area for grain and, to some extent, for forage. Coes averaged 7.9 bushels to the acre. In the same 5 years, milo on a comparable plot produced 12.5 bushels. Coes matured no grain in 1949 and 1950 because stands were not obtained until too late for the crop to mature. Good yields of forage, however, were obtained in these years.

Early Sumac Sorgo

A series of methods-of-seedbed preparation were carried with Early Sumac sorgo, a variety grown chiefly for forage, for the 17 years 1932–48. The methods used were practically the same as those used for corn, but the sorgo was grown on the same land each year, whereas corn was alternated with winter wheat or barley.

The methods and average yields are shown (table 11). The 4 fall-listed plots averaged 10.0 bushels of seed and 3,513 pounds of stover. Planting on fall listing by splitting the ridges without intervening cultivation gave the lowest yield of the fall-listed plots. This method proved to be impractical because of weeds. The plot was usually green with weeds by planting time. Many of these were not killed by the planting operation and became troublesome later.

TABLE 11.—*Seed and stover yields of Early Sumac sorgo under different methods of seedbed preparation, Colby (Kans.), 1932–48*

Seedbed preparation and planting method	Average acre yield	
	Seed	Stover
Fall-listed:	*Bushels*	*Pounds*
Fall-listed, spring-leveled, lister-planted	12. 4	4, 042
One-wayed, fall-listed, spring-leveled, lister-planted	11. 2	3, 734
Fall-listed, spring-leveled, lister-planted by splitting ridges	9. 0	3, 327
Fall-listed, lister-planted by splitting ridges	7. 5	2, 950
Average on fall listing	10. 0	3, 513
Spring-listed:		
Spring-listed, lister-planted by splitting ridges	6. 9	2, 951
Spring-listed, leveled, lister-planted by splitting ridges	6. 9	2. 888
Spring-listed, leveled, lister-planted in some furrows	6. 4	2. 815
Average on spring listing	6. 7	2, 885
Spring one-wayed, lister-planted	4. 8	2, 423
Spring-plowed, lister-planted	6. 3	2, 681
Lister-planted without previous cultivation	3. 7	2, 062

The spring-listed plots averaged 6.7 bushels of seed and 2,885 pounds of stover, appreciably less than the fall-listed ones. There was little difference between methods of spring listing.

Plowing early in the spring and then planting with a lister had substantially the same results as early-spring listing. One-waying or undercutting with sweeps early in the spring was less productive than plowing.

The lowest average yield was 3.7 bushels of seed and 2,062 pounds of stover on lister planting without previous cultivation. By sorgo-planting time, weeds had usually made considerable growth and had used up enough moisture to make the seedbed somewhat dry and cloddy. It was hard for the plants to get started on account of the poor seedbed and the shortage of moisture. This method proved to be impractical because of poor stands and, later, trouble in getting rid of the weeds.

Sorgo was harvested with a binder, leaving a short stubble. This stubble did not afford adequate protection against soil blowing and did not catch much snow in the winter. Listing in the fall proved effective in preventing soil blowing and in storing winter moisture, as well as in providing a warmer and finer seedbed at planting time.

The yields of seed were low under all methods. Early Sumac sorgo is an excellent forage crop (fig. 10), but is too late in maturing to produce high yields of seed in most years.

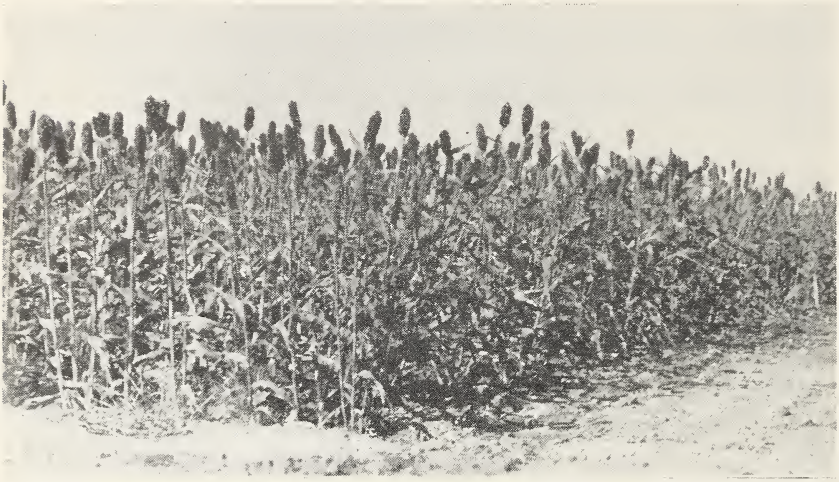

FIGURE 10.—Early Sumac sorgo at the Colby Branch Station. It is a dependable forage crop.

A series of rotations was started in 1940 to compare sorgo on cropland with that on fallow. These consisted of continuous sorgo, sorgo alternating with fallow, fallow followed by 2 years of sorgo, and a 4-year rotation in which the sorgo was planted on fallow following winter wheat. The sorgo was planted with a lister. Seed was produced in every year except 1949. For the 10-year period 1941–50, the 3 fallowed plots averaged 19.2 bushels and the cropland plots 9.7 bushels.

As Sumac sorgo is grown for fodder, the total production is more important than the yield of seed, which is rather unpalatable. The total production of seed and stover of the 3 fallowed plots averaged 8,210 pounds; and that of the 2 cropped plots, 5,050 pounds.

Some fodder was produced every year on both fallow and cropland. Fallowed-sorgo land was as productive as fallowed winter-wheat land. The 3 plots on fallow produced good yields of forage every year, outyielding the cropped land by a considerable margin each year.

Beans

Beans are an important crop in some sections of the Great Plains. In these experiments beans were grown 1920–50 in a single 2-year rotation with winter wheat. Pinto beans were used the first 15 years.

They are rather late maturing and often were not fully ripe at wheat-seeding time. An earlier variety, Great Northern, has been used since 1935. Beans were planted with a surface planter in 40-inch rows on spring-plowed land. The average yield for 31 years (1920–50) was 3 bushels to the acre. As the crops failed completely in 13 of the 31 years, it would seem that beans are not adapted to this area. They did not withstand the hot, dry spells in summer as well as other crops did. Bean ground was favorable for wheat, except that the surface soil was usually dry and finely pulverized and blew readily when not protected by growing wheat. In most years beans did not use all the subsoil moisture.

Fodder

As sorghums and corn are grown for feed as well as for grain, the weight of fodder (grain and stover combined) is often an important consideration. Fodder yields are more dependable than grain yields, since stover is produced in some years when grain is a complete failure. In no year was fodder a complete failure under all methods, although there were a number of years when yields were very low.

Fodder yields for corn, milo, and kafir in comparable sequence are shown (fig. 11). The milo grown during the period shown was

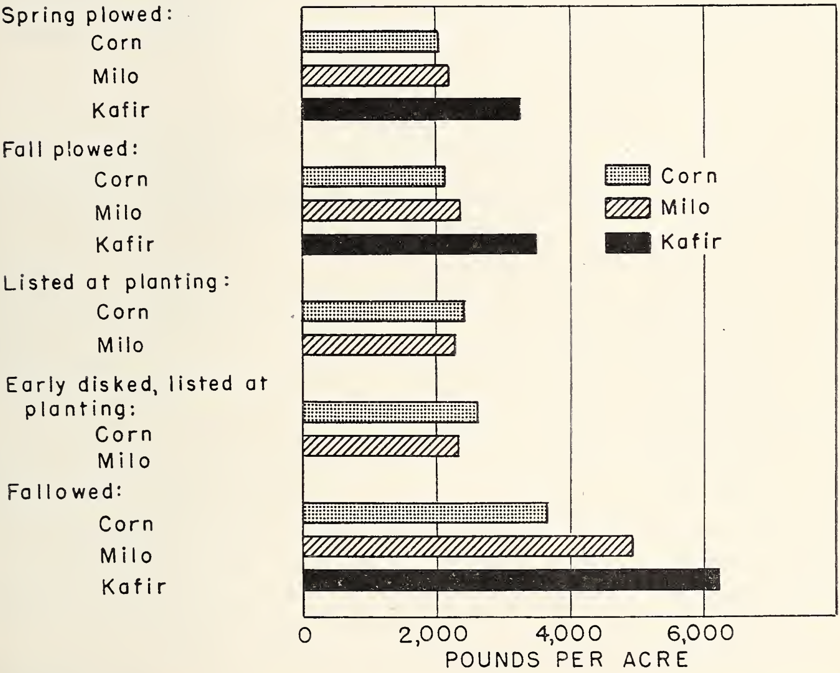

FIGURE. 11.—Fodder weights of corn, milo, and kafir grown under comparable tillage practices, Colby (Kans.), 1915–37.

Dwarf Yellow, which produces more and better quality forage than do most of the combine types.

Production of forage from corn and milo was much the same except on fallowed land, although milo was a little more productive than corn on surface-planted land and a little less productive when lister planted. Kafir yields were much higher than those of corn and milo. The most significant fact shown is the much greater response to fallow by sorghums than by corn.

Approximate, but not exact, comparisons between kafir and Early Sumac sorgo are available for the 10-year period 1941–50. The comparative acre yields of fodder are:

	Approximate yields
	Pounds
On cropped land:	
Kafir	3,350
Earl Sumac	5,050
On fallow land:	
Kafir	8,230
Early Sumac	8,210

Fodder yields of Early Sumac sorgo are also available for a 17-year period on the group of annually cropped plots (table 11). The fodder yield on fall listing was about 1,000 pounds to the acre higher than on spring listing.

Fodder weights were taken on Coes, a combine type sorghum, in only 2 years. In these 2 years, the yield was 3,190 pounds to the acre. Early Sumac sorgo and corn from comparable methods produced 4,900 and 2,050 pounds to the acre, respectively.

Straw

Straw yields of the principal crops were obtained, 1915–30, when the crops were binder harvested. The average yields for the different crops were:

	Straw yields
	Pounds per acre
On cropped land:	
Winter wheat	1,750
Spring wheat	1,260
Oats	1,050
Barley	1,120
On fallowed land:	
Winter wheat	3,000
Spring wheat	2,460
Oats	1,870
Barley	2,120

These straw yields represent the amount of straw available for feed or bedding when the crops were binder harvested. They are also indicative of the quantity of straw returned to the land when the crop is combined. Winter wheat produced considerably more straw than did spring grains on both cropped and fallowed land.

MISCELLANEOUS MANAGEMENT PRACTICES

Effect of Barnyard Manure on Winter Wheat and Milo

The effect of manure was studied in two 4-year rotations consisting of fallow, milo, fallow, wheat. In one rotation manure was applied to the land being fallowed for milo. Thus, each plot in this rotation received 10 tons of manure to the acre every fourth year. The other rotation was a check without manure.

The average acre yields of grain and straw or stover for the 2 rotations were:

	Wheat		Milo	
	Grain	Straw	Grain	Stover
Rotation:	*Bushels*	*Pounds*	*Bushels*	*Pounds*
Unmanured	18. 7	2, 760	26. 4	3, 860
Manured	17. 5	2, 750	25. 5	3, 770

Grain yields are for the entire 36-year period, straw for the period 1915–30, and stover for the period 1915–37.

Results from a group of 3-year rotations of fallow, wheat, milo are given (table 12). These data show the ineffectiveness of manure in improving yields of winter wheat and milo. In no instance was the

TABLE 12.—*Effects of straw and manure on average yields of winter wheat and milo in ten 3-year rotations of fallow, wheat, milo, Colby (Kans.), 1915–50*

Treatment	Rotation [1]	Acre yield of—			
		Winter wheat		Milo	
		Grain	Straw [2]	Grain	Stover [3]
	Number	*Bushels*	*Pounds*	*Bushels*	*Pounds*
Check	551	22. 3	3, 170	14. 4	2, 180
Straw (tons per acre) topdressed on wheat:					
3	554	20. 5	3, 230	14. 1	2, 250
Manure (tons per acre) topdressed on wheat:					
3	555	22. 0	3, 170	13. 6	1, 970
6	556	20. 8	2, 920	12. 6	1, 900
Check	552	20. 4	2, 710	12. 6	1, 800
Manure (tons per acre) applied before listing for milo:					
3	557	20. 1	2, 990	12. 8	1, 810
6	558	20. 2	3, 220	14. 7	2, 070
9	559	19. 5	3, 210	14. 8	2, 120
12	560	18. 5	2, 980	14. 1	2, 140
Check	553	20. 5	2, 970	14. 6	2, 130

[1] The field location of these rotations is the same as their arrangement in this table.

[2] 1915–37.

[3] 1915–30.

yield of a manured rotation materially above that of the adjoining check. There was some indication that wheat grain yields may have been depressed slightly by topdressing with straw and by the 9- and 12-ton applications of manure to milo.

Manure was also applied at the rate of 3 tons per acre as a topdressing on winter wheat grown continuously on early-fall plowing. The average yield for the 19-year period during which this practice was followed was 7.7 bushels per acre. This is substantially the same as the yield of comparable plots not receiving manure.

From these experiments, it appears the barnyard manure has not materially affected the average yields of winter wheat or milo on either fallow or cropland. More luxuriant growth on manured land took place early in the season in certain years when there was ample moisture in the soil. This resulted in exhaustion of moisture earlier than on unmanured land unless there was above-average rainfall. In some years of plentiful moisture, there was more lodging of wheat on manured than on unmanured plots, with consequent reduction in yields. In most years, however, manure did not seem to be a decisive factor.

Green-Manure Crops in Rotation

The effect of green manures on the crops immediately following has been mentioned in the discussion of different crops. The effect of such crops on the rotation as a whole are presented (table 13). Green manuring is compared with fallow, since each involves the loss of land for a year.

Table 13.—*Average yields of milo and winter wheat in green-manured and comparable rotations, Colby (Kans.), 1915–47*

Rotation	Acre yields			
	Milo		Winter wheat	
	Grain	Stover [1]	Grain	Straw [2]
	Bushels	*Pounds*	*Bushels*	*Pounds*
Winter rye plowed under, milo, fallow, winter wheat	20. 3	3, 330	20. 5	2, 410
Field peas plowed under, milo, fallow, winter wheat	20. 6	3, 310	19. 6	2, 280
Fallow, milo, fallow, winter wheat	25. 4	3, 860	18. 9	2, 760
Fallow (manured), milo, fallow, winter wheat	24. 6	3, 770	17. 6	2, 750

[1] 1915–37.
[2] 1915–30.

Yields of milo immediately following the green-manure crop were lower than on fallowed land, presumably because of the moisture used in producing the green-manure crop. Winter wheat in these rotations was grown the third year after the green-manure crop was plowed under.

The grain yields of wheat seemed to be slightly increased and the straw yields appreciably decreased in the green-manured rotations.

Fallow was substituted for the green-manure crop for the period 1948–50. During these 3 years, grain yields of both milo and wheat in the green-manured rotations were almost exactly equal to those in the fallowed rotations. Straw and stover were not harvested for yield.

Commercial Fertilizers

Results from manure, and from occasional applications of commercial fertilizers to station fields, were so negative that any intensive study of commercial fertilizers appeared unproductive. However, favorable reports in western Kansas in some recent years, particularly 1947, made it seem advisable to start a simple fertilizer experiment to see how frequently a response would be obtained.

The experiment consisted of 4 treatments replicated 6 times. The treatments were: (1) No fertilizer; (2) 25 pounds N; (3) 25 pounds P_2O_5; (4) 25 pounds N and 25 pounds P_2O_5.

The experiment was started in the dry fall of 1949, and the stands obtained were not uniform. The average yield in 1950 was 15.9 bushels per acre. No significant difference was shown between treatments. The experiment was repeated in the fall of 1950, but in this experiment, as elsewhere on the project, the wheat was winterkilled.

Subsoiling

Subsoiling has often been advocated for crop production in dryland areas. An experiment with it was begun in 1915 and continued until 1936, a period of 22 years. By 1936, it had become evident that any benefit fell far short of compensating for the extra cost, and the experiment was discontinued.

Subsoiling was done in the fall. The land was plowed to the same depth (7 inches) as other plots, and the subsoiler was run to an additional depth of 8 inches in every other plow furrow, thus stirring the soil to a depth of 15 inches. Subsoiling was completed for 2 consecutive years and then omitted for a like number of years. Both crops were surface planted.

Comparative yields with subsoiling and ordinary fall plowing for the 22 years were:

	Yield	
	Grain	Stover
Treatment:	*Bushels*	*Pounds*
Corn on fall plowing	12.5	1,300
Corn on land fall plowed and subsoiled	13.6	1,340
Milo on fall plowing	10.0	1,930
Milo on land fall plowed and subsoiled	11.2	2,550

Grain yields were about a bushel to the acre higher on the subsoiled plot, and the yield of milo stover about 600 pounds to the acre higher.

Subsoiling did not decrease the number of failures. In every instance where the crop on ordinary fall plowing failed, the one on subsoiled land also failed.

Soil moisture samples to a depth of 6 feet were taken in the fall before plowing or subsoiling and again in the spring for a period of 5 years. Differences in moisture content between plowed and subsoiled plots were within the range of experimental error.

Response of Different Crops to Fallow

The effect of fallow on yields has been mentioned in the discussion of individual crops. A comparison of the different crops is presented (table 14). In this table, the best method of continuous cropping is compared to the plots alternately cropped and fallowed.

TABLE 14.—*Comparison of annual cropping with alternate fallowing and cropping for 8 crops, Colby (Kans.), 1915–50*

Crop	Acre yields		Increase from fallow		
	Best method of continuous cropping	Alternate fallow and crop			
	Bushels	*Bushels*	*Bushels*	*Pounds* [1]	*Percent*
Winter wheat	8.9	17.6	8.7	522	98
Spring wheat	5.4	8.4	3.0	180	56
Oats	16.8	26.0	9.2	294	55
Barley	15.2	26.8	11.6	557	76
Corn	15.6	22.7	7.1	398	46
Milo	12.5	26.2	13.7	795	110
Kafir, grain	7.9	20.1	12.2	732	154
	Pounds	*Pounds*		*Pounds*	*Pounds*
Kafir, total weight	2.760.0	5,330.0	--------	2.570	93
Sorgo, total weight [2]	4,770.0	8,470.0	--------	3,700	78

[1] The following bushel weights were used in this and in other tables: Winter wheat, spring wheat, and kafir, 60 pounds; oats, 32 pounds; barley, 48 pounds; corn, 56 pounds; and milo, 58 pounds.

[2] 10 years, 1941–50.

Grain yields of milo and kafir were increased more by fallowing than were those of other crops. Barley produced the next highest number of pounds of grain increase, but the value of the increase was less than that of winter wheat, because of its lower price per pound.

Corn, oats, and spring wheat gave increases for fallowing too small to justify their regular production by that method. Any fallowed land available in the spring can best be utilized by growing milo or barley.

The effect of fallow on fodder and straw yields has already been discussed, but the fodder yields of kafir and sorgo are presented (table 14) for comparison with grain yields.

Most of the ground fallowed in this area is seeded to winter wheat. Usually, other crops are grown on fallow only when the winter wheat seeded on it has to be abandoned. The good response of the sorghums to fallow indicates that it is a sound practice to grow the forage as well as the grain needed for the livestock on the farm on fallowed land.

In fallowing for spring-sown crops, it is essential that extra precautions be taken to protect the bare fallow from blowing during the winter and spring. The amount of surface tillage usually necessary to control weeds leaves fallowed land too fine and smooth to resist blowing. In the fall, before the ground freezes, the surface should be roughened with a chisel or other shovel type implement that brings clods to the surface. This operation may cover all the land or it may be done in strips. The chisels or shovels are usually spaced 2 to 4 feet apart, but close enough so that the area covered has enough clods on the surface to resist blowing. In strip cultivation, the strips should be close enough together to protect the ground between them.

Ordinarily, the strips should not be more than 2 rods apart if they are to afford much protection. The ground between strips may be cultivated later if soil blowing threatens to become serious. Similar precautions are normally necessary on row-crop land where the crop has been removed and only a short stubble is left.

When winter wheat, either on cropped or fallowed land, does not make enough fall growth to cover the surface, strip cultivation is often necessary to roughen the surface and protect the crop from soil blowing.

Pasturing Winter Wheat

Pasturing winter wheat during the fall, winter, and early spring is a common practice in this area whenever the crop becomes well established in the early autumn. Returns from wheat pasture form an appreciable part of the income from wheat on most farms. Many farmers are of the opinion that judicious pasturing does not injure wheat and may increase the yield in some years. Fall and winter pasturing have been accepted more as a matter of course than spring pasturing.

In these experiments, pasturing was not practical and none of the crops were grazed. An experiment was started in 1931, however, to determine the effect of removing spring growth of winter wheat on fallow by mowing or plucking instead of pasturing. Triplicate plots were laid on wheat sown on different dates, with a check plot adjacent to each mowed or plucked plot. The wheat was clipped with a lawn mower or a sickle in 1931 and was plucked off by hand in 1934, at heights of 2 to 4 inches above the ground in both instances. There was not enough growth to warrant removal of any of it in 1932 and 1933.

The first clipping was done the last week of March. Two subsequent clippings were done in April and two in May; one clipping was done in June in 1934 only. The forage removed was weighed, and grain yields were obtained on all plots.

The results indicated that removing the fall and winter growth late in March did not have a marked influence on the yield of grain. A second clipping the last week in April reduced the average yields by about one-half. A fourth clipping between the 5th and 10th of May reduced yields to about one-fourth of those from the check plots. This clipping reduced the yields to a point where it would have been more profitable to have used the entire crop for pasturage than let it mature grain. Clipping the last week in May or early in June practically stopped growth and resulted in no yield of grain.

Substantial yields of green forage were obtained from all clipped plots. Frequent clippings yielded more green forage but reduced the stand and weakened the plants. The clipped plots made faster growth between clippings than the check plots, except following the late clipping.

In the years 1935–41, wheat did not make enough early spring growth to warrant repeating the experiment· In the spring of 1942, winter wheat started early and growth was unusually rank by the middle of April. The experiment was resumed on a reduced scale. Favorable years for wheat pasture continued, and the experiment was repeated in each of the succeeding 8 years. During these years, the clipping was done only once each spring, at a time when wheat was making rapid growth but was not jointing appreciably. This was usually about the middle of April, but in some years it was as late as the first week in May. The growth ranged from 4 to 10 inches in height in the different years, and averaged about 6 inches.

The 9 years were similar in that wheat did not suffer seriously from lack of moisture at any time. The yield was appreciably above average except in 1949, when a promising crop was hailed out just before harvest. In 1943 and 1950, the rainfall between clipping and harvest was much lower than in any of the other years, but there was an abundance of moisture in the subsoil.

In 1942, when moisture conditions were extremely favorable up to the time of clipping and there was an excess of precipitation the rest of the season, removal of the luxuriant growth the middle of April resulted in an appreciable increase in yield. In 1943, removal of growth the middle of April did not greatly influence the yield. In the other 6 years (except 1949), clipping decreased yields from 7 to 45 percent. The greatest reductions were in 1944, 1947, and 1948 when the removal of growth was delayed until May. The 8-year average yield of the clipped plot was 30.5 bushels, compared with 35.8 bushels for the check plots.

These results indicate that pasturing-off fall and winter growth before mid-April will not lower the yield appreciably and may occasionally increase it. Judgment must be used in pasturing, however, to prevent creation of a soil-blowing hazard. Pasturing after the middle of April is likely to decrease yields substantially.

SOIL MOISTURE

Moisture is the chief limiting factor in crop production in the Great Plains. Soil-moisture studies have been a part of these experiments during the entire period. When the experiments were started in 1914, soil samples were taken on each plot to a depth of 8 feet, to determine texture and water-holding capacity. Moisture determinations to varying depths have been made each year on a number of plots to ascertain the soil moisture content and its use by crops. The minimum point to which a crop can reduce the water content of the soil was determined from these samples. The amount of water above this minimum point is the water available for use by the crop.

Storage of Moisture by Fallow

Fallowing involves leaving land without a crop for a year or more. During this time it is allowed to store moisture from precipitation for the use of a subsequent crop. The standard method of handling fallow for these studies was to leave the stubble undisturbed during the fall and winter, and in the spring until the middle of May when the land was moldboard plowed about 7 inches deep. After plowing, the ground was kept clean with surface-tillage tools. From 1 to 3 operations were necessary to keep the plots free of weeds during the summer. The aim was to have a rough, somewhat cloddy surface that would absorb and hold moisture from summer rains and would not blow readily. A firm seedbed was also an objective.

Soil samples were taken at intervals, to find out how much moisture was stored in the soil during the fall, winter, and summer and during the entire fallow period. Samples were taken in foot-sections, usually to a depth of 6 feet, and the moisture content was determined separately for each foot of depth. Most of the work was on winter-wheat plots.

Comparable data on plots alternately cropped and fallowed are available for 25 years for the 3 portions of the fallow period. The average rainfall and the average quantity of water stored for each period were:

Period:	Precipitation *Inches*	Water stored *Inches*
Harvesttime to wheat-seeding time in fall	6.24	0.07
Seeding time in fall to spring	5.04	3.96
Spring to wheat-seeding time in fall	12.65	—.14
Entire fallow period	23.93	3.89

The average figures indicate that practically all the moisture was stored during the winter period when the land was in stubble. However, the quantity stored in the different periods varied greatly between years.

The change in water content from harvesttime to wheat-seeding time ranged from a gain of 3.11 inches to a loss of 4.30 inches. Gains occurred chiefly when the soil was extremely dry at harvesttime and rainfall was above average. Heavy losses occurred when the soil held considerable water at harvesttime, because this water was consumed by full growth of weeds and volunteer wheat. There was a small gain in 12 and a small loss in 13 of the 25 years.

During the period between wheat-seeding time in the fall and the start of active growth in the spring, conditions were favorable for moisture storage. Weeds had been killed by freezing shortly after wheat seeding, the stubble caught snow and protected the soil from direct evaporation, and temperatures were low. These factors contributed to low evaporation. Gains in moisture content were made consistently during this period. The only exception was a slight loss in a year when the soil held considerable water in the fall and the winter precipitation was low. In a few instances the water stored exceeded the precipitation, evidently because of snow blown from other plots and caught by the stubble. The maximum gain shown was 14.06 inches for the 1945 crop. The soil was dry in the fall; and the spring sampling was done after a period of heavy rains, when the moisture content of the soil was considerably above the quantity that could be held for more than a temporary period. The practical limit of moisture storage was about 8 inches.

During the period from spring until wheat-seeding time in the fall, there was a small average loss in moisture content, although the average rainfall for the period was 12.65 inches. Gains were made only when the soil was extremely dry in the spring or when the summer rainfall was excessive. Losses were heaviest when the spring moisture content was high and the summer precipitation low. The greatest gain was 5.33 inches in a year when the soil was dry in the spring and the rainfall between spring and wheat-seeding time in the fall was 24.31 inches. Material gains were made only in years when the rainfall between spring and wheat-seeding time exceeded 15 inches. Losses were recorded in 13 of the 25 years.

Data for the period from spring until wheat-seeding time in the fall are available for most years that the experiments were in progress. When all of the years are included, the period shows a slight gain.

The average gain for the entire fallow period during the 25 years was 3.89 inches. This amounts to only 16 percent of the rainfall. The maximum quantity of water stored in any year was 9.48 inches, when 31 percent of the 30.23 inches of precipitation was stored. The highest proportion stored in any fallow period was 36 percent, which represents storage of 5.52 inches from a rainfall of 15.22 inches.

Losses for the entire fallow period occurred in a few years, generally when there was considerable water in the soil at the beginning of the fallow period.

Moisture Storage Under Five Different Methods of Fallow

Moisture determinations were made by using 5 different methods of fallow for winter wheat for the crop years 1916–20. During 4 of these years, determinations were made for the 3 portions of the fallow periods discussed in the preceding section. Minor differences were shown between somewhat similar methods, but it is believed that the best information can be gained by combining the data from similar methods (table 15). Three methods where the land was plowed or listed immediately after wheat harvest are combined in the first entry; these are compared with two methods, combined in the second entry, where the wheat stubble was left undisturbed until plowed the followlowing May.

The two groups showed substantially the same water storage for the whole fallow period, but there were striking differences in the season in which it was stored. The plots plowed or listed after harvest gained considerable moisture during the period from harvest to wheat-seeding time, while the plots in stubbleland showed little gain. Winter gains were much higher on the plots in stubble than on those where

TABLE 15.—*Inches of water and percentage of the precipitation stored in the upper 6 feet of soil during the fallow period for 4 years, 1916, 1917, 1918, and 1920, Colby (Kans.)*

Treatment	Periods											
	Harvesttime to wheat-seeding time in fall			Seeding time in fall to spring			Spring to wheat-seeding time in fall			Entire fallow period		
	Precipitation	Water stored		Precipitation	Water stored		Precipitation	Water stored		Precipitation	Water stored	
		Total	Percentage of precipitation		Total	Percentage of precipitation		Total	Percentage of precipitation		Total	Percentage of precipitation
	Inches	*Inches*	*Percent*	*Inches*	*Inches*	*Percent*	*Inches*	*Inches*	*Percent*	*Inches*	*Inches*	*Percent*
Plowed or listed shortly after harvest	5. 65	1. 53	27	4. 39	1. 42	32	16. 00	2. 74	17	26. 03	5. 69	22
Stubble left undisturbed until May plowing	5. 65	. 11	2	4. 39	3. 36	77	16. 00	1. 97	12	26. 03	5. 44	21

it had been turned under. Gains between spring and seeding time in the fall were low for both methods, but slightly in favor of the plowed plots.

The 4 years represented (table 15) were above average in precipitation and in the percentage of moisture stored.

As mentioned in the discussion of crop yields, there are factors other than moisture storage that make it desirable to leave the stubble on the surface over winter.

Hard-Surface Versus Loose-Surface Soil

Soil-moisture determinations were made for 6 years (1914–19) on 2 small plots, to compare the effectiveness of a clean, smooth, hard surface and a rough, loose soil mulch in storing moisture. The smooth-surface plot was kept clear of weeds by cutting them off with a hoe without disturbing the surface appreciably. The other was tilled frequently to keep the surface rough and loose throughout the growing season as far as possible.

When the plots were first sampled on July 17, 1914, they were fairly uniform in moisture content. They contained no available moisture except a little in the first foot.

The results show that a rough, loose surface is much more receptive to moisture than a smooth, hard surface. After the upper 2 or 3 feet become filled with moisture, it is difficult, under field conditions, to increase appreciably the moisture content of these or of lower depths unless rainfall is very heavy. This is especially true when the surface is hard and smooth, so that it does not trap or retain water. The plot with the smooth, hard surface showed no evidence of water reaching the fifth and sixth foot-sections until 1916, and they did not become really wet until 1919. Water reached the fifth and sixth foot-sections of the plot with the loose surface in 1915. This zone appeared to be fully wetted in 1916, and it remained in that condition until the end of the experiment.

At the end of the 6 years, the hard-surfaced plot had 8 inches more and the loose surfaced one 9.1 inches more than when the first sample was taken. This probably represents about the maximum quantity available to wheat that the soil will hold.

Moisture Storage by More Than 1 Year of Fallow

It was found, in the mulch and in other moisture studies on fallow, that in years when the moisture content of the soil was high at the start of the fallow period, there was only a slight gain or even a loss during the subsequent fallow period. There are, however, many years so dry that land with little moisture present at wheat harvest fails to accumulate much during the fallow period. Four such years occurred in the early thirties, when 1 year of fallow stored 6.01 inches of water in 1933, 0.95 inch in 1934, 2.14 inches in 1935 and 2.06 inches in 1936. During this same 4-year period, another block of plots later used for experiments was fallowed continuously. These plots gained an average of 9.18 inches of water in the 4 years.

This block of plots was seeded to wheat in the fall of 1936, and it produced 15.1 bushels to the acre in 1937. Wheat on 1 year of fallow failed in 1935 and in 1936, and it yielded 5.5 bushels in 1934 and 2.7 bushels in 1937—a total of 8.2 bushels for the 4 years. Thus, wheat on 4-year fallow produced almost twice as much in the 4 years as wheat on 1-year fallow. There was little storable precipitation in any of those 4 years, except in 1933 for the 1934 crop.

An experiment involving 2 years of fallow was started during this period of dry years. The ground was fallowed 2 years, followed by 2 crops of wheat.

Moisture determinations for 8 years beginning with the 1942 crop provide a comparison between the amounts of moisture stored by 1 year of fallow and by 2 years of fallow on the same plots. As an average for the 8 years, the first year of fallow stored 4.07 inches of water and the second year of fallow an additional 1.90 inches. The precipitation in all but one of these years was much above average. In 4 of the 8 years, the moisture content of the soil in the upper 6 feet was slightly lower at the end of the second year of fallow than at the end of the first year. In 3 years much more moisture was stored the second year than the first. The moisture content at the end of the first year of fallow was comparatively low in all 3 instances. In 1 of these years, there was slightly less moisture at the end of the first year of fallow than at the beginning, but the land gained more than 6 inches of water the second year. In 1 year when the soil was well filled with water at the beginning of the first fallow year, there was a slight loss of moisture during both fallow years.

These results indicate that fallowing for more than 1 year is a doubtful practice for storing moisture, except when the moisture content at the end of the first year of fallow is exceptionally low. It may not be profitable even under those conditions. In this experiment, in each of the 3 years when the moisture content was low at the end of the first year of fallow, high precipitation while the crop was growing made up the deficiency, and high yields of wheat were obtained. The extra moisture stored the second year did not increase the yields above those of plots fallowed only 1 year.

Moisture Storage With a Basin Lister

The basin lister was compared with the ordinary lister for fallowing wheat-stubble ground for wheat, and for preparing wheat-stubble ground for wheat after wheat, 1937–51. In this experiment, 3-year rotations consisting of 1 year of fallow followed by 2 crops of wheat were used. The basin lister has an attachment which makes dams in the lister furrow about every 10 feet, forming basins to keep more of the precipitation from running off. Soil-moisture determinations to a depth of 6 feet were made over a period of 7 years, 1939–45, to evaluate the effectiveness of the basins in storing moisture.

The 7-year average gain of the plots fallowed with the ordinary lister was 4.8 inches of water. Those fallowed with the basin lister gained 5.2 inches.

Wheat stubble listed after harvest with an ordinary lister for the second crop of wheat gained an average of 1.1 inches of water between harvest and seeding. The basin-listed plots gained 1.0 inch.

There was no significant difference between the basin lister and the ordinary lister in the amount of water stored during the fallow period, or during the period from harvest to seeding for the second crop of wheat. The difference in the average yield of wheat produced was less than ½ bushel to the acre, either for the wheat on fallow or for the second crop after fallow.

Conservation of Winter Moisture

The average winter precipitation at this station is less than one-fourth of the total for the year, yet it is important in moisture conservation. The efficiency of different types of cover in retaining winter moisture is shown by moisture determinations for 2 different years (table 16).

TABLE 16.—*Water conserved over winter under different plant cover and surface conditions, Colby (Kans.), 1914–15 and 1915–16*

Surface conditions	1914–15		1915–16	
	Precipitation	Water stored	Precipitation	Water stored
	Inches	*Inches*	*Inches*	*Inches*
Winter-wheat stubble: [1]				
Undisturbed	6. 65	5. 22	3. 24	1. 44
Fall-listed	6. 65	4. 65		
Fall-plowed	6. 65	3. 06	3. 24	. 76
Milo stubble [1]	6. 65	3. 87	3. 24	. 62
Corn stubble [1]	6. 65	3. 47	3. 24	. 82
Green-manured land	6. 65	2. 08		
Fallowed land	6. 65	1. 66	3. 24	. 29

[1] The stubble left in harvesting with a binder.

Storage was affected, not only by the type of surface cover, but also by the roughness of the surface and the quantity of water already in the soil.

Small grain stubble was more effective in conserving winter precipitation than was row-crop stubble. Fall-listed land conserved more water than was conserved by row-crop stubble, and much more than was retained in plowed land. Green-manured land and fallowed land were relatively smooth; they were high in moisture at the beginning of winter, but conserved the least moisture during the winter. It seems probable that listing row-crop land with little vegetative cover might be effective in storing moisture as well as in preventing soil blowing. Furrowing bare fallow to prevent blowing might also help conserve winter moisture.

Studies of winter moisture storage were also made on land where a crop of winter wheat was growing. Water use by the crop was probably not an important factor, because winter wheat is small or dormant over much of the period. The 30-year average gain of land seeded to winter wheat each year was 1.34 inches on late-fall plowing, 0.91 inch on early-fall plowing, and 0.25 inch on fallowed land. The late-fall-plowed plot was much cloddier and drier than the early-plowed plot and had a smaller growth of wheat. Early-plowed ground was usually looser and rougher than fallowed land and had less wheat growth. The condition of the surface was the most important factor in determining winter storage. A wheat-stubble plot adjacent to the cropped land stored an average of 3.73 inches of water during the same period of years.

Data were recorded for 18 years covering a rotation in which wheat was grown on corn stubble, on fall-plowed wheat stubble, and on standing wheat stubble. The average precipitation for the winter period was 5.45 inches. The increase in moisture during the winter was 1.52 inches on corn stubble, 1.07 inches on fall-plowed land, and 3.13 inches on wheat stubble. These figures agree well with data obtained on land where no crop had been seeded.

A single plot where wheat was stubbled-in each year increased its moisture content by 2.46 inches during the same period of years.

Penetration of Rains

No special determinations were made in connection with these experiments on the penetration of each individual rain; but in a number of the dry years, shallow soil samples were taken in 3-inch sections at frequent intervals, so the movement of water into the soil could be noted. These samples were taken on ground being fallowed and on sod, 1936–37; and on fallowed land planted to wheat and on land being fallowed for wheat, 1938–40. In 1941 the soil was wet to a depth of 3 feet in the spring on both plots and shallow samples were discontinued, but some deeper samples were taken. In the spring of 1951, following the extremely dry period from September to April, samples were taken on sod.

The samples taken in 3-inch sections showed that showers resulting in precipitation of about 0.25 inch wet the soil from 1.5 to 3 inches. Showers of between 0.25 and 0.5 inch of rainfall wet to a depth of 2 to 6 inches, averaging about 3 inches. Rainfalls of about 1 inch wet down to about 6 inches; those of about 1.25 inches, from 6 to 9 inches; those of about 1.5 inches, from 6 to 12 inches; and those of about 2 inches, 12 to 15 inches. A 5-inch rainfall wet wheat stubble to a depth of about 2 feet. Showers of less than ¼ inch did not usually increase the moisture content of the soil appreciably.

These figures show that the same quantity of rain does not always wet to the same depth. Factors other than the quantity of water provided by the rain, such as character of the rain, the physical and moisture condition of the soil, and weather conditions immediately following the rain, helped determine how deep water would penetrate.

The difference in the depth of penetration of a given rain on land growing a crop and on land being fallowed was much smaller than might have been anticipated. With rainfall up to 1 inch, this difference was usually within the range of 1 or 2 inches. With heavier rains, close comparisons were not possible, because at depths below the level where the soil had been at least partly dried by surface evaporation, there was frequently no line of demarcation between the newly wet soil and soil remaining wet after earlier rains. In general, slow rains penetrated deeper than equal quantities of rain falling more rapidly. A part of this might have been caused by runoff, but some of it was due to the fact that moisture had a chance to penetrate deeper before rapid evaporation from the soil surface commenced.

These studies emphasized the lack of storage of water on fallowed land during the summer, and the heavy losses by evaporation from land being fallowed. Such land dried rapidly in the upper 3 inches, a little less rapidly to a depth of about 6 inches, and progressively slower as the distance from the surface was increased. During a prolonged drought, there was an appreciable loss of water from the second foot-section. Most of the water from all but the heaviest rains was used in replacing that lost by surface evaporation.

Heavier rains caused deeper penetration on fallowed land, but the additional depth was small in comparison with the water required to accomplish it. Deep penetration of water was sometimes more than counterbalanced by water lost from the upper foot-section in the dry, hot weather that frequently precedes seeding.

The lack of water storage during hot weather on land being fallowed may be emphasized by illustrations. In 1936 the soil on land being fallowed was wet to a depth of about 15 inches when the first sample was taken on May 9, and to a depth of 2 feet when the sample at time of seeding was taken in mid-September. The available water in the soil, however, was slightly lower at seeding than in May, because the surface 6 inches of soil was much drier. Rainfall during the period was 6.47 inches. A similar situation prevailed in other years. In 1938, there were 12.71 inches of rain between the spring sampling and seeding, but fallow gained no moisture. It was wetter in the second foot at seeding but drier in the first. In both 1937 and 1940 the soil was wet deeper at seeding than in the spring, but it contained no more water. All these were years when conditions for moisture storage were adverse. As shown earlier, there was some moisture storage during the summer in more favorable years.

An extreme case of difference in water penetration on land already wet and on land with less moisture was shown in 1941. Land being fallowed was wet to a depth of 4 feet and land in wheat stubble was wet to a depth of about 2 feet when soil samples were taken on July 19. A rain of 5.15 inches fell during a 22-hour period on July 25. Samples taken July 31 showed the stubbleland wet to a depth of 4 feet, but only a little of the water had penetrated more than 4 feet on the fallow land. The moisture content of the stubbleland was increased by 4.52 inches and that of the fallow land only 1.79 inches during this period. In this instance, the surface cover as well as the quantity of water already in the soil greatly influenced penetration.

One of the best illustrations of water penetration into a dry soil occurred in 1951. The soil in native sodland was practically dry the first part of May. Rains totaling 1.29 inches, May 13–15, soaked the soil to a depth of 7 inches. Rains amounting to 3.07 inches, May 18–22, wet an additional 9 inches or a total of 16 inches. Moisture penetrated the soil 2 inches deeper by May 30 without additional rain. Rains amounting to 3.12 inches fell between June 6 and 11 and wet the soil an additional 3 inches, or a total of 21 inches. This moisture reached a depth of 24 inches by June 20. Thus, about 7.8 inches of rain over a period of a month wet the soil to a depth of only 2 feet. Part of the quantity lost was used by the grass, but much of the loss resulted from evaporation. During the same period, water reached a depth of 3.5 feet on tilled land that had been in wheat or milo.

The shallow samples showed one other feature. Where a crop was growing rapidly or the land was in weeds or sod, the moisture content of the soil below the depth of that reached by rains was usually being steadily reduced while the surface soil was being wetted by intermittent rains and dried by evaporation and plant use. There were few rains during the active growing season of wheat that affected the soil to a depth of as much as a foot.

Available Moisture in Soil at Seeding Time and Its Effect on Yield

Not all of the moisture in a soil is available to crops. When crops have removed all they can, there still remains a residue. Water in excess of this quantity is termed the available water, and is the only part of the soil water that is used in crop production.

The available moisture in the soil was determined for each year 1915–50 under each of 3 methods of cultivation—late-fall plowing, early-fall plowing, and summer fallowing. The quantity of water in the soil at seeding time under each of these methods and the resulting yields are given (appendix table 36). For convenience, the moisture present is expressed as inches of water. The depth to which an inch of water will thoroughly wet this soil is about 6 inches.

The depth to which a soil is wet bears, with some explainable exceptions, a fairly definite relationship to the quantity of water that it holds. Annual data on this point are presented (appendix table 37). In this table, a soil with an available water content of 3 percent (about ½ inch of water) or more is considered wet. A soil with less than 3 percent available water is considered dry. Thus, a foot-section of soil that is considered wet may lack being entirely wet by a considerable amount and a soil considered dry may contain some available water. The 3-percent line of demarcation, however, appears to be about as good as could be selected.

Table 37 shows at a glance how infrequently cropped land is wet to a depth of more than 1 foot. It also shows the regularity with which fallowed land is wet to 2 feet or more and the much greater depth attained in most years. The table further shows that a foot-section of dry soil did not become wet unless all of the soil above it was wet. The only exception to this appears to be on the continuously cropped plots in 1950. The water present in the fourth foot-section of soil at seeding time for the 1950 crop was water not removed before harvest in 1949 by a hail-damaged crop.

The relationship between the quantity of water in the soil and the depth to which the soil was wet can be noted by comparing appendix tables 36 and 37. Less than 1.5 inches of water in the soil usually indicate that the soil was wet in the first foot only. Soils wet into the second foot generally contained approximately 1.5 to 3 inches of available water. Soils wet into the third foot held more than 3 inches of available water. Data for soils wet to depths greater than 4 feet were available for the fallowed plots only. Where the soil was wet into the 5th foot-section, it contained an average of 6.2 inches of water. Soil wet into the 6th foot contained an average of more than 8 inches of available water.

These relationships are good enough for practical purposes, but there are exceptions. When the soil is shown to be wet to a depth greater than can be attributed to the water content, it means that some foot-sections contain less water than they are capable of holding. This may be due either to a residue left at harvest by a previous crop, or to reduction in moisture content of the upper foot-sections of soil brought about by long-continued drought preceding the samplings at seeding time.

Since the depth to which the soil is wet and the quantity of available water present compare closely, discussion of one of these factors seems sufficient; the results can be applied to the other. The data are discussed on the basis of the quantity of water in the soil, because this factor lends itself more readily to statistical interpretation.

Perhaps the simplest test by which to measure a relationship between the 2 factors is the correlation coefficient. Such coefficients were calculated for the quantity of available water in the soil at seeding time, and the yield for each of the 3 treatments separately as well as for the 3 combined. The results are given (table 17).

Table 17.—*Correlations between the quantity of available water in the soil at seeding time and the yield of winter wheat at Colby (Kans.), 1915–50*

Treatment	Correlation coefficient	Correlation coefficient necessary for significance at 1 percent level
Late-fall plowing	0. 560	0. 418
Early-fall plowing	. 438	. 418
Summer fallowing	. 545	. 418
All 3 treatments	. 613	. 254

The coefficients, although not high, are all significant at the 1-percent level. It is probably not accidental that the correlation for early-fall plowing is lowest. This method provides a soil condition favorable to good fall and early-spring growth without providing enough moisture to carry the crops far toward maturity. As a consequence, in years with low rainfall between seeding and harvest, this method often suffered more severely from drought than did the others.

There is also a sound reason why the combined analysis for all 3 treatments should be higher than the others. The individual analyses for the 3 methods take into consideration only the relation between water content and yield of a given method in different years. The combined analyses include differences between methods in the same year.

The relationship between water at seeding and yield is the one important factor in crop production that can be determined at or before seeding, and thus serve to influence practice. Considering all that may happen between the time a crop is seeded and harvest (discussed under a later section on crop hazards), it seems remarkable that such a relationship exists.

The effect of the quantity of water on the yield is further brought out by dividing the amount of water at seeding time into 3 categories: 0–1.4 inches, 1.5–2.9 inches, and 3 inches or more. The percentage of years in these 3 categories and the resulting yields are presented (table 18).

TABLE 18.—*Percentages of 35 years falling into 3 different categories of amounts of available water at seeding time, and resulting wheat yields, Colby (Kans.), 1915–50* [1]

Treatment	Inches of water available at seeding time—					
	0 to 1.4		1.5 to 2.9		3.0+	
	Percentage of years	Average acre yield (bushels)	Percentage of years	Average acre yield (bushels)	Percentage of years	Average acre yield (bushels)
Late-plowed	74	6. 3	17	15. 0	9	21. 7
Early-plowed	60	6. 2	29	9. 1	11	14. 8
Fallowed	11	5. 5	17	6. 3	72	23. 0

[1] The year 1949 was not included in this correlation because the wheat crop was destroyed by hail.

This table emphasizes the high percentage of time that land seeded to wheat contained less than 1.4 inches of available water, and the equally high percentage of time that fallowed land contained more than 3 inches.

The yields resulting from the different quantities of water at seeding time are also shown in this table. When there was 0 to 1.4 inches, the average yield was low on all 3 treatments. When the water content ranged from 1.5 to 2.9 inches, yields were higher than where less water was present, but there was a considerable difference between treatments.

The percentage of years in which the water content was between 1.5 to 2.9 inches was too small for much reliance to be placed on the average figures, but there seems to be a sound reason why early plowing produced less than late plowing. Most of the years in which early plowing contained 1.5 to 2.9 inches of water while late plowing did not, were years in which the water content of early plowing was barely above 1.5 inches. The average water content of late plowing in the category of 1.5 to 2.9 inches was 0.7 inch higher than that of early plowing in the same category.

Years in which fallowed land did not contain more than 2.9 inches of water were generally years of such adverse weather conditions that near crop failure occurred on fallowed land as well as on land receiving other treatments. In 8 of the 10 years in which fallowed land contained less than 3 inches of water, the yield of wheat on such land was 5 bushels to the acre or lower. Complete failure occurred in 4 of these years.

The certainty of production and the average yields were increased greatly when the soil contained more than 3 inches of water at seeding time. However, the number of times this occurred in soil where wheat followed wheat was too small for the average figure to be considered reliable. Wheat on fallowed land contained 3 inches or more of water in most years, and much more than 3 inches of water in some years. Confidence can be placed in the average yield figure.

Adequate water at seeding helps to insure good crops, but it does not provide absolute assurance that a crop will be realized. This is brought out by table 19, which shows the yields in different yield categories from different quantities of water in the soil at seeding time. When the soil contained 1.4 inches or less of water at seeding, over half of the yields might be considered failures—74 percent of the yields were below 10 bushels to the acre, and no yield of as much as 30 bushels was produced.

TABLE 19.—*Percentages of yields in different yield categories resulting from different quantities of water in the soil at seeding time, Colby (Kans.), 1915–50*

Water at seeding time (inches)	Yield categories, bushels per acre—				
	0–9	10–19	20–29	30–39	40+
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
0.0–1.4	74	18	8	0	0
1.5–2.9	67	17	12	4	0
3.0–4.9	15	46	31	0	8
5.0+	15	15	40	20	10

With successively higher quantities of water, the percentage of yields below 10 bushels to the acre are reduced. With more than 5 inches of available water at seeding time (this occurred on fallowed land only), the percentage of yields below 10 bushels was reduced to 15, and yields of 20 bushels or more could be expected in more than two-thirds of the years. Two of the 3 yields of more than 40 bushels to the acre were obtained when the soil contained more than 5 inches of water at seeding, and the content was barely below 5 inches in the third year.

The 3 low yields with 5 inches or more of water at seeding time resulted from adverse conditions after seeding. In 1933, precipitation during the growing season for wheat was so low that not even the wheat on fallow could produce grain. In 2 other years, a combination of low rainfall and high temperatures held yields below 10 bushels to the acre. The year 1951 (not included in table 19) was another year of failure with adequate water at seeding. The wheat came up to a good stand, but continued dry weather baked the soil beneath the surface mulch so that brace roots could not penetrate.

Most of the wheat died during the winter before rains heavy enough to permit brace-root development occurred.

The successive increases in size of crop, resulting from increased quantities of water present at seeding time, is emphasized (table 19). The fact that no quantity of water at seeding is large enough to be a complete insurance against failure is also brought out.

The extent to which rainfall after seeding time influences yield is shown by the number of times rainfall from seeding to June 15 overbalanced the quantity of water at seeding in determining the final yields. June 15 was selected as the final date because rains after that time are too late to alter yields materially. The effects of water on soil at seeding time on fallowed land and on cropped land are discussed separately in the following paragraphs.

There were 10 years in which fallowed land contained less than 3 inches of water at seeding time. The yield was below the average for the method in 9 of these years, although precipitation between seeding and harvest was above average in 4 of them. Thus, there was only 1 year in 4 in which poor conditions at seeding time were corrected by rainfall after seeding, and only 1 year in 10 in which an average yield was obtained with less than 3 inches of water at seeding.

There were 25 years (not including 1949) with more than 3 inches of available water in the soil at seeding time. Low precipitation between seeding and harvest reduced the yield to below average in only 6 of the 13 years in which it occurred, or less than one-half of the time. Low yields from other causes occurred in 2 years in which precipitation was above average. There was less than 1 chance in 4 that the yield on land with 3 inches or more of available water would be brought below average by low rainfall from seeding to harvest.

Continuous cropping shows similar results, although smaller quantities of water are involved. There were 23 instances in which either the early- or the late-plowed plots contained 1.5 or more inches of water at seeding time. Rainfall from seeding to harvest was below average in 12 of these years, but the yield was brought below average in only 6 of them.

There were 47 instances in which the moisture content at seeding was below 1.5 inches. In 14 of the 22 years in which rainfall from seeding to harvest was above average, the yield was above average.

For continuous cropping as a whole, there was 1 chance in 4 that favorable seeding conditions would be negated by low rainfall after seeding. There was a little better than 1 chance in 3 that, with less than 1.5 inches of water at seeding, above-average yields would be brought about by above-average rainfall. Factors other than water at seeding or precipitation after seeding determined the final yield in relatively few years.

CROP HAZARDS

Moisture is the chief determining factor in crop production in this area, and drought is the principal hazard in farming. Moisture conservation is accomplished mainly through the control of weeds, which are a constant hazard. Many other factors often are important hazards in the production of crops. In the 36 years of the experiment, there were only 7 without appreciable soil blowing. In some of the wettest years, serious damage to winter wheat and other crops occurred before the young plants emerged or had enough growth to cover the ground. Duststorms were common during droughty years; they were especially severe 1933–40, during which period there was extensive soil blowing at frequent intervals. There were only 11 years when there was no appreciable damage to crops by hot winds.

The bitter-cold winds that often accompany snow in winter have been more of a hazard to livestock than to crops. There have been days nearly every winter when high winds piled the snow in drifts, leaving many fields practically bare. In 19 of the 36 years, there were one or more days when snowstorms were of blizzard proportions. In 5 of these years, severe blizzards caused heavy losses of livestock. Wheat on fields swept bare by high winds during snowstorms was exposed to damage from low temperature and soil blowing.

In 21 years, winterkilling of wheat occurred. Losses were severe in 9 of these years, causing heavy abandonment. In only 4 years—1919, 1942, 1943, and 1947—was there practically no abandonment of winter wheat in the spring. Winterkilling was closely associated with drought and with low winter temperatures.

In most years there was severe damage to crops from destructive hailstorms in some localities in the area. In some years, particularly the wet ones, damage to wheat and other crops by hail was serious and extensive. There was an appreciable amount of hail at the station in 16 of the 36 years; in 5 of these, considerable damage resulted. In June and August of 1917, the damage to trees and growing crops was fairly extensive. In 1949, wheat and other small grain crops were almost completely wiped out by hail on June 27.

Late-spring frosts frequently killed the blossoms on the fruit trees and also the young fruit, and occasionally damaged corn, spring-sown small grains, and even winter wheat. Noticeable damage to winter wheat at this station occurred in 1931 and 1938. In 1945 and 1947, extensive damage to winter wheat in other localities was reported. Early-fall frosts frequently prevented sorghum crops from maturing satisfactorily.

In 9 years, rank growth of straw induced by heavy rains late in May and June resulted in damage to winter wheat and other small grains. Appreciable losses were caused by rainy weather during harvest in 8 years. Lodging of sorghums by high winds in the fall was serious in some years.

Rabbits were numerous enough in most years to constitute a pest. In 1934, 1935, and 1936, they did so much damage by pasturing the young wheat plants in winter that drives were organized to reduce their numbers.

Insects were an ever-present continuing hazard, but in most years their damage was not extensive. Grasshoppers did appreciable damage in many years by destroying the newly emerged wheat along the edges of fields in the fall, by cutting off the heads of ripening small grains, and by defoliating cornfields after small-grain harvest. In some years extensive poisoning was necessary to control grasshoppers and prevent widespread damage. Hessian flies were numerous enough to do extensive damage in 1924 and appreciable localized damage in 1931 and 1951. This insect was present in small numbers in other years. Greenbugs were prevelant in wheat and other small-grain fields in the spring of 1950. They did widespread damage, and some fields were sprayed as a control measure. They were also numerous in the spring of 1951 but did little damage. Wheat straw-worms were present in 1924 in nearly all stems of wheat below the head and above the first joint, but did not damage the crop much. Straw-worms, jointworms, and stem maggots were present in damaging numbers in some wheatfields in 1931. The common cutworm was found in considerable numbers in most years. Army cutworms did considerable spring damage to wheat and other small grains in 1942 and 1951. The pale western cutworm destroyed many acres of small grains in 1938, 1939, 1940, and 1941. An unidentified worm, locally called the "false wireworm," did considerable damage in some fields of seeded wheat during a dry fall when the seed did not germinate promptly. A species of white grubworms thinned the stands of wheat in some fields in the fall of 1944, 1945, and 1947.

Plant diseases were prevalent in some years. In 1923 wheat was practically destroyed by stem rust. There was also appreciable damage from stem rust in other years, including 1915, 1937, and 1944. Foot rot was destructive in many fields in some years. Injury from this disease was noted on the station in 1928, 1944, and 1946. Mosaic disease of wheat was prevalent in 1949 and, to some extent, in 1951. Loose smut has been prevalent in winter and spring barley in many fields in recent years, reducing the yields appreciably. Periconia root rot was prevalent in the milo plots in 1938. Weak neck caused considerable local damage to milo in some years.

Minor damage to crops has been caused by other insects and diseases through the years. Accidental fires during harvest have been a serious hazard at times, burning many acres of wheat and other small grains. These fires were especially numerous in 1942 and 1943, causing heavy losses.

EFFECT OF CROPPING ON THE SOIL

The land on which these experiments were conducted was broken out from native sod about 1885, farmed for a few years, and then allowed to return to native sod. The sod was broken again in 1905. At the time experiments were started in 1914, the land had been farmed continuously for about 10 years. Analysis of the soil on the rotation field in 1916 showed that it contained only about 70 percent as much carbon and about 75 percent as much nitrogen as native sod. In 1946 the sod contained approximately the same amounts of carbon and nitrogen as it contained 30 years earlier. The rotation field, however, contained on the average only about two-thirds as much carbon and four-fifths as much nitrogen as in 1916. The highest losses of both were on fallowed or row-crop land; the lowest, on land where small grains had been grown continuously. The loss was greater where fallow was alternated with row crops than where it was alternated with small grains.

The soil has undergone a few changes in its physical properties. A plow sole has been noted on some plots that have been plowed frequently. Careful analysis by soil physicists might reveal other changes that have taken place in the physical properties. On most of the plots, however, these properties are not noticeably different now from what they were 37 years ago.

When the plots were laid out in 1914, the surface soil on about a fourth of the area had been eroded appreciably by wind during the duststorm period 1912–14. During the first few years, this eroded portion was more sticky that other plots and did not turn up as mellow in plowing. This condition has improved even under continuous cropping to row crops. In 1914 dust was piled several inches deep in a strip down the center of the field covering about 2 acres. For several years crops on this strip grew more luxuriantly but dried up much sooner than on other plots. This condition improved, but no appreciable difference has been noted in recent years.

There has been noticeable water erosion where a block of plots (several in a row) have been fallowed frequently or have been in row crops continuously. Through the years some of the small-grain plots that have been in stubble during the winter have accumulated soil blown from roads or other plots.

The soil does not appear to have changed enough to affect crop yields materially under the prevailing climatic conditions. Certain characteristics, however, seem to have persisted throughout the years. From the beginning of these experiments, rotation 2 has outyielded similar rotations 7 and 9. Rotation 566–2 has consistently outyielded a similar rotation, 566–1. The two plots in rotation 565 have been less productive every year than other plots in that part of the field. The plots in rotations 406 and 407 have invariably been harder to plow than the plots in rotations 574 and 575.

The average precipitation and yields of the different crops are shown by 5-year periods on cropland and on fallow by methods used throughout the 36 years (table 20). It is difficult to tell whether the productivity of the soil has changed, because the precipitation and other conditions have varied during the different 5-year periods. There was only a fraction of an inch difference between the average precipitation during the second 5-year period and the sixth and seventh periods. For winter wheat, spring wheat, and oats, there was not much difference between the average yield for the second and the seventh periods. For barley and corn, yields averaged lower in the sixth and seventh periods than in the second. This was probably attributable to the fact that rainfall distribution during the last two 5-year periods was much more favorable for wheat than for barley and corn. Kafir produced somewhat higher yields during the second than in more recent periods, but the difference was smallest on fallowed land. Milo yields averaged as high during the sixth as during the second period, but a better adapted variety was used.

Some of the highest small-grain yields on record were obtained in recent years. The 1947 yields of winter wheat on some of the cropland and fallow plots were the highest ever obtained. Plot A (winter wheat) produced its highest yield (29.8 bushels) in 1947 after being in winter wheat continuously for 34 years. Plots A and B (oats) produced their highest yields (52.5 and 61.3 bushels, respectively) in 1947 after being in oats continuously for 34 years. These results indicate that the soil can still produce high yields when climatic conditions are favorable.

Table 20.—*Precipitation and yields of winter wheat, spring wheat, oats, barley, milo and kafir by 5-year periods on continuously cropped plots A and B and on fallow plots C–D, 1915–50*

Plot and period	Precipitation	Acre yields of—						
		Winter wheat	Spring wheat	Oats	Barley	Corn	Milo	Kafir
A—CONTINUOUSLY CROPPED ON LATE-PLOWED LAND								
	Inches	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1915–19	19. 89	11. 1	7. 1	15. 3	17. 3	16. 3	9. 9	7. 1
1920–24	21. 44	15. 3	6. 3	21. 6	24. 9	22. 9	17. 9	18. 2
1925–29	16. 35	6. 7	3. 4	13. 6	16. 3	7. 9	4. 8	3. 7
1930–34	15. 65	7. 1	4. 5	16. 8	12. 8	6. 2	10. 9	10. 8
1935–39	13. 55	1. 5	1. 7	3. 1	2. 2	. 5	3. 5	0
1940–44	21. 51	11. 5	6. 4	21. 6	19. 3	16. 5	24. 6	13. 2
1945–49	21. 98	10. 8	7. 4	32. 2	18. 1	7. 5	13. 4	3. 4
B—CONTINUOUSLY CROPPED ON EARLY-FALL-PLOWED LAND								
1915–19	19. 89	10. 0	9. 4	17. 5	21. 3	17. 3	10. 7	5. 7
1920–24	21. 44	11. 4	9. 4	25. 2	28. 2	25. 8	20. 1	18. 6
1925–29	16. 35	6. 3	2. 5	13. 1	16. 6	5. 6	4. 5	4. 4
1930–34	15. 65	8. 2	4. 5	18. 5	16. 2	6. 1	8. 8	10. 7
1935–39	13. 55	1. 8	1. 5	3. 0	1. 3	. 2	2. 4	0
1939–44	21. 51	8. 7	5. 6	18. 0	13. 5	15. 9	19. 1	12. 9
1945–49	21. 98	9. 0	6. 3	25. 0	17. 9	7. 0	12. 6	3. 8
C–D—ALTERNATELY CROPPED (EACH OF THE 2 PLOTS ALTERNATELY CROPPED AND FALLOWED)								
1915–19	19. 89	13. 5	10. 5	22. 0	29. 4	24. 7	14. 4	8. 0
1920–24	21. 44	21. 7	12. 9	41. 0	44. 3	41. 1	45. 0	28. 8
1925–29	16. 35	19. 3	8. 2	25. 4	33. 9	19. 7	13. 1	18. 5
1930–34	15. 65	21. 7	9. 2	31. 9	27. 4	20. 0	30. 0	32. 5
1935–39	13. 55	2. 4	2. 5	5. 7	3. 1	3. 0	5. 6	1. 5
1940–44	21. 51	21. 0	7. 5	24. 1	24. 1	23. 2	40. 2	26. 8
1945–49	21. 98	26. 6	11. 1	41. 4	34. 5	26. 6	34. 0	19. 2

SUMMARY AND CONCLUSIONS

This circular reports the results of experiments in crop-rotation and tillage methods at the Colby (Kans.) Branch Experiment Station during the years 1915–50. The station is located in the northwestern part of the State.

The soil is a brown silt loam of high fertility. It is a deep, friable soil, easily worked and well adapted to the production of a variety of crops.

The average annual precipitation for the 37-year period, 1914–50, was 18.48 inches. The average for the 6 months, April to September, was 14.24 inches. More than three-fourths of the precipitation falls during the growing season.

Winter wheat is the chief crop, usually exceeding the acreage of all other crops in the area combined. Other crops grown widely are barley, oats, and corn, as well as milo and other grain and forage sorghums.

During these experiments the yields of winter wheat on fallow averaged practically double the yields of the best methods on cropland. Over the years no tillage method or rotation used in growing wheat on land cropped every year was effective in producing a substantial increase in yields. Moisture storage on cropped land varied little under different tillage methods and crop sequences.

In summer fallowing it is essential that the weed growth be effectively controlled and that the surface of the soil be kept rough and cloddy enough to take in moisture readily and to resist blowing, and at the same time form a firm seedbed. In these experiments there was no marked difference between any of the various methods of fallow that met these objectives.

The standard method of fallow used was to leave the wheat stubble undisturbed over winter and until about the middle of May. The stubble was then moldboard-plowed, and the land was kept clean the rest of the season with surface-tillage tools.

It was found that the lister, the duckfoot or subsurface sweeps, and even the one-way disk plow, if judiciously used, could be substituted for the moldboard plow without materially affecting yields.

The yields of wheat on fallow from fall plowing left rough over winter and from May plowing averaged the same. When plowing for fallow was delayed until mid-June, the average yield was lowered by almost 4 bushels to the acre. Methods of fallow that leave the ground in stubble, rough, or in ridges over winter to catch and hold snow and to resist blowing, were more satisfactory than those that leave the surface bare and smooth.

The second crop of wheat after fallow produced yields about equal to those on land cropped continuously to wheat. Undercutting the heavy wheat stubble for the second crop after fallow or drilling wheat into the heavy stubble without previous cultivation was not satisfactory when the following spring was wet and cold. The wheat was somewhat yellowish and spindly, apparently because of a lack of available plant food. This was true of any method where a heavy cover of crop residue remained on the surface.

Fallowing 2 years or more in succession was not profitable except in very dry years when only a small quantity of moisture was stored during the first fallow year and conditions were unfavorable at seeding time. A much larger portion of the precipitation is usually stored during the first year of fallow than in succeeding years.

Plowing every year after harvest apparently leaves the soil too loose for best results. Plowing at less frequent intervals has given somewhat higher yields than plowing every year. On the average and in most years, one-waying, stubbling-in on cropland, shallow cultivation, and subsurface cultivation yielded about as well as plowing.

Packing the soil with a subsurface packer after plowing for winter wheat in the fall was not a determining factor in yield in most years. Under certain conditions the use of the packer has proved beneficial in resisting blowing, in facilitating seeding on trashy ground, and in firming the seedbed on spring plowing for spring crops.

Drilling wheat in undisturbed wheat stubble year after year on the same land proved to be a poor method chiefly because of grassy weeds which cannot be satisfactorily controlled without cultivation. The yields were appreciably lower than when land was drilled in the stubble of wheat that had been seeded on ground tilled for the preceding crop.

Use of the basin lister for fallow or for the second crop after fallow did not increase the average yield of wheat above that obtained with an ordinary lister.

Winter-wheat yields following corn or milo were approximately equal to those following wheat.

Winter wheat following corn in 80-inch rows and beans in 40-inch rows produced appreciably higher yields than following crops that utilize the moisture in the soil more fully. Bean ground blows readily, and the yields of wheat after beans were reduced by wind erosion in some years.

The yields of spring wheat were very low in comparison with other crops, indicating that this crop is not adapted to the area. On fallow, spring-wheat yields were less than half those of winter wheat.

Fairly satisfactory yields of oats were obtained on cropped land. The various methods of tillage caused little difference in average yields. Oats did not give as good response to fallow as did some other crops.

Barley was the highest yielding small-grain feed crop. Continuous barley yielded about as well as barley in rotations. It responded to fallow somewhat better than did oats or corn. Barley was a satisfactory crop to sow where wheat on fallow had been abandoned early in the spring.

Corn planted with a lister yielded appreciably more than corn on ground plowed and surface planted, and withstood the summer heat and drought better. Slightly better yields were obtained when corn was grown continuously than when it was grown under comparable cultural methods in a rotation. Corn was less responsive to fallow than was winter wheat or the sorghums. Corn grown in 40-inch rows averaged approximately 50 percent more grain than when grown in 80-inch rows.

Average milo yields for the 36-year period were slightly lower on cropped land than were those of corn. In more recent years, since adapted combine types of milo were introduced, milo has outyielded corn. It yielded about as well when grown continuously as when grown in rotations. When grown under different methods of seedbed preparation after wheat, highest yields were obtained on fall listing when the ridges were leveled early in the spring.

Milo is well suited to growing on fallow. Its yields on fallow in comparison with its yields on cropped land were higher than those of any other crop. Milo is the most satisfactory crop to plant where winter wheat on fallow has been abandoned. Its chief drawbacks are the uncertainty of obtaining a good stand, and the likelihood of damage by frost in the fall before the crop is mature.

Kafir seldom matured before frost. Its yields on fallow averaged more than twice as much as the yields of kafir grown continuously.

Feterita averaged approximately 3.5 bushels less than milo under comparable methods. Stands were difficult to obtain but the grain usually matured before frost. Coes sorghum, which was substituted for feterita after 1945, is a more productive, quick-maturing crop.

Early Sumac sorgo was grown chiefly for forage. It is too late-maturing to produce satisfactory yields of seed in most years. However, it produced good yields of high-quality forage. For the years that it was grown, sorgo on cropped land produced almost twice as much total fodder as corn or milo, and appreciably more than kafir. In fodder yields on fallow, Early Sumac sorgo averaged approximately the same as kafir, almost twice as much as corn, and about a fifth more of better quality fodder than milo. Early Sumac sorgo averaged almost two-thirds more fodder on fallow than on cropped land.

Dry beans in a rotation with winter wheat averaged 3 bushels to the acre.

The use of barnyard manure did not materially increase or decrease the grain, straw, or stover yield of winter wheat or milo, on either fallow or cropland.

No differences between the effects of winter rye and field peas as green-manure crops was apparent. Yields of winter wheat and milo following these crops were somewhat lower than on fallow. No cumulative beneficial effects of their use were apparent.

Commercial fertilizers did not appear to influence the yields of wheat on fallow appreciably in 1950, the only year in which they were tested.

In these experiments, subsoiling did not appreciably affect the yields of corn and milo or the moisture content of the soil.

All crops grown produced increased yields on fallow. Kafir, milo, and winter wheat showed the greatest increase in yield on fallow as compared with yields on cropped land. Barley did not respond as well to fallow as did winter wheat, but it responded appreciably better than did oats or corn.

Corn and the sorghums showed approximately the same response to fallow in total fodder as in grain alone. Sorghum was vastly superior to corn in yields of forage on fallow, as compared with yields on cropped land.

Clipping the fall and winter growth of winter wheat in the early spring, to simulate pasturing, did not appreciably lower the yields, and in some years it resulted in increased yields. Clipping after the middle of April, however, reduced yields substantially.

Under the standard methods of fallow, an average of 3.7 inches of water was stored in the upper 6 feet of soil during the entire fallow period. This was approximately 16 percent of the precipitation.

More moisture was stored in the soil when a rough, loose surface mulch was maintained than when the surface was comparatively smooth and hard. After the upper 2 or 3 feet of soil became filled with moisture, it was difficult to increase the moisture content of lower depths appreciably.

When fallow is continued more than 1 year, more moisture is usually stored the first year than in subsequent years.

The basin lister was not appreciably more effective over a 7-year period than was the ordinary lister in storing moisture in fallow or in wheat-stubble ground.

Much of the moisture stored by fallow was stored during the winter months. Small-grain stubble conserved more of the winter precipitation than did row-crop stubble, fall-plowed ground, or bare fallow.

The depth to which rains penetrate into the soil depends on various factors, such as the amount of moisture already in the soil, the capacity of the soil to absorb and hold moisture, and the character of the rains. Showers of less than one-fourth inch did not usually increase the moisture content of the soil appreciably. Torrential rains added less moisture in proportion to their volume than gentle rains.

A close relationship was found between the moisture content of the soil at seeding time and the yield of winter wheat.

Drought is the chief hazard to crop production in this area. Soil blowing is also a serious hazard, especially in dry years. Weed control is important in both wet and dry years. Other hazards, usually less widespread, are blizzards, hail, winterkilling, late-spring frosts, early frosts in fall, overabundance of rabbits, and ravages by insect pests and plant diseases.

The soil in the rotation field has lost much of the carbon and nitrogen it contained when the sod was first broken with a plow. Changes in the physical properties of the soil also occurred.

Average yields of most crops for the last 5 years of the experiments compared favorably with the average for the second 5 years, when the precipitation averaged about the same. On some of the plots the highest yields were obtained in 1947, after 34 years of cropping to the same crop.

Recent yields from these plots indicate that the productivity of the soil is still good enough to produce high yields when climatic conditions are favorable.

APPENDIX TABLES

TABLE 21.—*Monthly, seasonal, and average evaporation, in inches, Colby (Kans.), 1914–50*

Year	April	May	June	July	August	September	Seasonal, April–September
1914	4.59	5.74	8.98	7.97	8.88	7.59	43.74
1915	4.02	5.43	5.84	5.98	5.44	4.94	31.66
1916	4.42	7.07	7.15	11.23	8.83	6.84	45.53
1917	4.36	5.38	7.95	9.58	6.74	4.71	38.72
1918	3.75	7.50	8.09	8.46	9.21	4.81	41.38
1919	3.54	5.02	6.61	9.19	8.86	6.42	39.64
1920	3.06	4.06	6.81	7.50	5.26	6.02	32.72
1921	5.28	7.03	6.03	8.72	6.41	5.89	39.36
1922	3.54	6.50	8.36	9.06	8.30	6.84	42.59
1923	5.43	5.26	6.61	7.34	6.89	5.84	37.37
1924	5.61	6.71	7.87	10.19	8.64	6.28	45.31
1925	6.14	6.70	10.40	10.89	8.47	6.37	48.97
1926	5.34	7.31	8.52	11.48	10.35	6.29	49.29
1927	5.02	8.94	7.06	9.04	6.01	7.15	43.23
1928	6.12	5.95	5.23	7.36	8.77	7.15	40.58
1929	5.80	5.10	7.05	9.98	8.22	5.78	41.94
1930	4.82	5.55	7.63	9.50	7.54	5.04	40.08
1931	3.99	6.07	8.90	9.80	8.01	8.16	44.92
1932	5.73	7.59	6.87	10.34	9.15	6.29	45.97
1933	6.34	5.85	10.15	9.74	7.09	6.54	45.71
1934	6.29	9.42	11.22	13.54	10.65	6.34	57.45
1935	6.93	5.32	7.66	11.82	9.35	6.20	47.29
1936	5.25	6.56	9.69	12.18	9.64	6.80	50.11
1937	5.44	6.88	7.32	10.30	9.79	5.97	45.71
1938	4.77	5.30	7.67	9.22	10.63	6.22	43.80
1939	4.47	7.75	9.81	11.69	8.50	8.92	51.14
1940	5.21	7.11	10.18	10.50	7.65	5.33	45.97
1941	3.79	6.34	7.26	7.66	7.54	6.76	39.34
1942	4.21	6.16	6.04	9.60	8.06	5.24	39.32
1943	5.66	4.94	8.26	10.14	9.62	6.80	45.43
1944	2.89	6.73	7.15	7.33	7.78	5.98	37.87
1945	3.96	5.92	5.80	8.39	7.55	6.13	37.75
1946	6.19	6.63	9.05	9.02	9.55	6.52	46.95
1947	4.13	5.01	6.04	7.77	9.79	8.34	41.08
1948	7.14	6.55	6.79	8.52	8.40	7.31	44.71
1949	4.96	5.69	6.19	8.38	7.44	5.34	37.99
1950	5.42	5.88	9.34	7.29	6.45	4.86	39.24
Average	4.96	6.28	7.77	9.37	8.26	6.32	42.96

TABLE 22.—*Monthly, seasonal, and annual mean temperatures, in ° F., Colby (Kans.), 1914–50*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Seasonal, April-September	Annual
1914	36	30	40	53	60	73	75	75	68	54	46	22	67	53
1915	[1] 28	[1] 36	[1] 29	54	55	64	71	67	64	55	44	32	63	50
1916	[1] 23	[1] 35	[1] 46	46	60	67	79	75	64	51	39	25	65	51
1917	29	34	37	46	54	69	77	70	66	46	46	29	64	50
1918	[1] 21	[1] 36	[1] 47	44	62	75	75	77	59	56	37	29	65	52
1919	[1] 26	[1] 26	[1] 40	48	57	68	76	75	69	46	[1] 35	[1] 29	66	50
1920	32	34	42	43	58	68	74	69	67	57	38	30	63	51
1921	33	38	46	49	61	69	76	74	67	58	41	32	66	54
1922	24	27	38	48	59	72	75	77	69	54	40	30	67	51
1923	34	27	34	49	56	68	74	71	64	47	42	27	64	49
1924	25	32	29	50	54	70	74	75	61	55	40	17	64	49
1925	19	37	44	54	60	75	77	74	67	43	40	30	68	52
1926	31	38	38	47	63	70	77	77	64	55	36	27	66	52
1927	29	31	37	53	63	67	75	69	66	56	39	21	66	51
1928	33	31	41	47	61	62	74	73	64	52	38	30	64	51
1929	21	20	41	51	58	69	79	77	61	52	28	32	66	49
1930	15	42	36	54	57	69	78	76	66	50	38	31	67	51
1931	33	36	34	48	56	74	76	73	72	55	38	29	67	52
1932	23	36	32	52	63	68	80	76	64	49	39	20	67	50
1933	32	25	41	49	58	77	78	72	69	54	42	37	67	53
1934	34	32	39	52	67	76	84	79	61	56	42	30	70	54
1935	31	34	44	48	53	68	82	77	65	51	34	31	66	52
1936	25	18	41	49	63	75	81	80	66	50	38	32	69	52
1937	13	30	35	49	63	70	80	80	67	53	38	28	68	51
1938	30	33	43	51	59	72	78	80	69	60	36	31	68	54
1939	33	24	39	49	65	72	81	75	70	54	40	35	69	53
1940	11	29	39	49	61	73	80	73	67	58	35	34	67	51
1941	29	31	37	49	64	68	74	74	66	52	42	30	66	51
1942	23	26	39	52	58	67	78	74	62	53	39	32	65	50
1943	28	37	35	53	56	70	79	80	65	51	40	30	67	52
1944	30	30	33	43	62	70	74	74	65	54	39	29	65	50
1945	30	33	45	46	57	62	76	74	65	54	42	27	63	51
1946	31	36	46	57	55	71	77	74	67	51	37	36	67	53
1947	30	28	36	48	57	66	76	79	70	60	34	29	66	51
1948	27	28	31	56	60	69	75	75	69	53	36	29	67	51
1949	16	30	39	51	62	70	76	73	63	51	46	31	66	51
1950	25	37	36	47	57	72	72	70	63	58	37	34	64	51
Average	27	32	39	50	59	70	77	75	66	53	39	29	66	51

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[1] From U. S. Weather Bureau data.

TABLE 23.—*Dates of the last killing frost in the spring and the first in the fall, and the number of frost-free days, Colby (Kans.), 1914–50*

Year	Date of—		Days in frost-free period
	Last frost in spring	First frost in fall	
			Number
1914	May 13	Oct. 14	154
1915	May 20	Oct. 4	137
1916	May 15	Sept. 27	135
1917	May 7	Oct. 7	153
1918	May 9	Oct. 25	169
1919	Apr. 24	Oct. 9	168
1920	Apr. 29	Sept. 29	153
1921	Apr. 28	Oct. 9	164
1922	do	Oct. 7	162
1923	Apr. 24	Oct. 13	172
1924	May 14	Sept. 28	137
1925	Apr. 30	Oct. 18	171
1926	Apr. 28	Sept. 25	150
1927	Apr. 21	Oct. 8	170
1928	Apr. 22	Sept. 25	156
1929	May 1	Oct. 20	172
1930	Apr. 16	Oct. 17	184
1931	May 21	Oct. 27	159
1932	May 15	Oct. 4	142
1933	Apr. 15	Sept. 30	168
1934	Apr. 24	Sept. 20	149
1935	May 4	Oct. 9	158
1936	Apr. 21	Oct. 20	182
1937	Apr. 26	Nov. 2	190
1938	May 7	Oct. 19	165
1939	Apr. 21	Oct. 28	190
1940	Apr. 18	Oct. 15	180
1941	Apr. 20	Oct. 27	190
1942	Apr. 10	Sept. 25	168
1943	Apr. 19	Oct. 14	178
1944	May 5	Oct. 11	159
1945	May 15	Sept. 28	136
1946	May 10	Sept. 22	135
1947	May 28	Oct. 25	150
1948	May 11	Oct. 10	152
1949	Apr. 15	Oct. 21	189
1950	May 26	Oct. 22	149
Average	May 2	Oct. 11	162

TABLE 24.—*Monthly, seasonal, and annual wind velocity, in miles per hour, Colby (Kans.), 1914–50*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Seasonal, April–September	Annual
1914	------	------	------	------	------	7.2	4.8	5.9	6.2	6.2	------	------	------	------
1915	------	------	------	7.4	7.6	6.8	5.5	3.7	5.5	5.6	------	------	6.1	------
1916	------	------	------	8.1	8.8	7.4	8.1	6.8	6.7	8.3	6.3	7.4	7.7	------
1917	------	------	------	9.3	8.8	8.2	6.3	5.6	5.5	6.0	------	------	7.3	------
1918	------	------	------	10.3	10.0	6.2	6.8	7.0	6.4	6.0	------	------	7.8	------
1919	------	------	------	9.0	7.1	5.5	5.9	4.7	5.6	4.8	------	------	6.3	------
1920	------	------	------	9.5	8.0	6.4	3.8	3.4	------	------	------	------	------	------
1921	------	------	------	9.2	9.6	5.2	5.7	4.2	4.9	------	------	------	6.5	------
1922	------	------	------	9.0	7.0	6.9	6.0	5.3	6.2	5.6	------	------	6.7	------
1923	------	------	------	------	8.2	7.5	4.5	4.0	5.3	5.9	4.7	5.3	7.5	------
1924	5.9	7.0	7.4	8.1	7.0	7.3	8.0	7.2	7.6	8.9	6.5	7.2	7.6	7.3
1925	6.7	6.7	8.2	8.8	7.5	9.1	6.3	7.0	7.1	6.7	6.7	6.8	7.9	7.3
1926	7.0	8.3	7.9	7.5	8.9	7.0	8.0	7.1	9.1	7.7	7.2	6.2	7.7	7.7
1927	7.3	7.0	10.6	8.8	10.8	7.7	6.1	5.2	7.4	6.0	5.9	5.9	6.6	7.4
1928	6.0	6.3	7.5	8.7	6.6	6.4	5.4	6.7	5.7	7.2	6.1	6.0	7.2	6.6
1929	6.6	6.5	8.1	9.1	8.6	6.1	6.8	5.3	7.4	5.6	6.5	5.2	6.1	6.8
1930	6.5	6.3	8.0	7.8	8.5	5.7	5.5	4.9	4.4	5.2	5.7	5.6	6.1	6.2
1931	5.0	5.1	7.4	7.2	7.4	7.1	6.6	5.6	7.2	7.0	6.6	5.8	6.9	6.5
1932	6.4	6.7	7.4	10.2	9.2	5.6	7.5	7.6	6.3	6.3	6.6	5.6	7.7	7.2
1933	5.7	7.5	9.3	9.4	7.8	8.2	6.5	6.2	6.4	6.1	6.3	5.8	7.4	7.1
1934	5.8	6.8	8.2	7.4	9.7	10.0	8.3	7.6	8.4	7.2	7.0	6.9	8.6	7.8
1935	6.6	7.3	10.2	11.9	9.7	7.9	7.1	6.8	6.0	6.1	4.8	5.9	8.2	7.5
1936	6.3	7.5	8.5	8.8	10.0	8.2	9.5	6.1	8.3	6.1	6.8	5.9	8.5	7.7
1937	7.5	8.0	7.9	9.6	9.4	7.1	6.3	7.7	5.6	6.0	6.1	5.1	7.6	7.2
1938	6.7	5.8	7.2	9.9	6.7	7.9	5.4	8.0	5.9	7.5	6.4	6.8	7.3	7.0
1939	7.7	7.7	6.8	8.5	7.8	9.1	7.8	6.3	7.5	6.3	5.6	5.9	7.8	7.3
1940	5.9	6.5	7.0	8.1	6.5	8.1	7.2	5.7	6.0	5.7	5.5	5.7	6.9	6.7
1941	4.8	5.7	7.2	9.9	7.8	6.9	5.1	4.3	6.8	5.4	4.4	6.2	6.8	6.2
1942	6.0	5.7	7.3	8.6	7.5	6.4	5.4	7.0	5.8	5.7	6.6	5.9	6.9	6.5
1943	6.9	7.2	7.3	7.8	6.9	7.5	6.5	5.7	7.0	5.6	6.1	5.4	6.9	6.7
1944	5.9	6.2	8.5	8.8	8.5	7.4	5.8	5.3	5.0	4.1	5.4	6.1	6.8	6.4
1945	5.5	5.9	6.4	7.6	7.1	6.0	5.5	5.2	5.8	4.5	5.7	5.3	6.2	5.9
1946	6.1	6.0	8.2	6.5	7.2	6.8	5.0	4.8	7.7	5.7	4.9	4.6	6.3	6.1
1947	5.6	6.3	6.8	7.3	6.9	5.7	5.4	6.3	6.2	5.4	6.6	4.3	6.3	6.1
1948	5.2	5.7	6.7	8.1	7.0	5.0	5.5	5.3	5.2	4.7	6.2	4.5	6.0	5.8
1949	5.6	5.6	6.6	6.2	6.5	4.9	4.9	5.0	5.6	5.6	4.4	5.4	5.5	5.5
1950	5.7	5.1	7.1	6.9	6.4	7.0	5.6	4.8	5.2	4.6	4.5	4.6	6.0	5.6
Average	6.1	6.5	7.8	8.6	8.0	7.0	6.2	5.8	6.4	6.0	5.9	5.8	7.0	6.7

TABLE 25.—*Monthly, seasonal, and average vapor pressures, in inches, Colby (Kans.), 1914–50*

Year	April	May	June	July	August	September	Seasonal, April–September
1914	[1] 0.216	[1] 0.315	0.485	0.557	0.485	0.357	0.402
1915	.309	.312	.468	.562	.507	.406	.427
1916	.195	.246	.432	.466	.442	.311	.344
1917	.194	.265	.336	.425	.456	.405	.347
1918	.185	.289	.408	.469	.433	.295	.347
1919	.241	.340	.504	.518	.446	.416	.411
1920	.202	.348	.481	.511	.511	.369	.404
1921	.202	.353	.507	.544	.563	.428	.433
1922	.228	.315	.455	.465	.483	.310	.376
1923	.205	.343	.545	.556	.523	.351	.421
1924	.188	.208	.445	.440	.480	.336	.350
1925	.230	.328	.400	.423	.485	.403	.378
1926	.180	.318	.377	.445	.431	.390	.357
1927	.250	.267	.423	.464	.502	.381	.381
1928	.184	.343	.439	.567	.452	.290	.379
1929	.204	.337	.429	.484	.496	.397	.391
1930	.308	.345	.463	.448	.532	.375	.412
1931	.225	.298	.483	.460	.446	.341	.376
1932	.208	.316	.466	.498	.508	.351	.391
1933	.177	.285	.385	.496	.503	.449	.383
1934	.180	.325	.425	.462	.478	.338	.368
1935	.170	.297	.465	.525	.515	.393	.394
1936	.210	.387	.396	.398	.444	.422	.376
1937	.230	.341	.431	.483	.478	.387	.392
1938	.262	.348	.443	.491	.458	.398	.400
1939	.231	.331	.366	.404	.439	.305	.346
1940	.221	.307	.418	.485	.508	.439	.396
1941	.279	.398	.501	.538	.497	.400	.436
1942	.276	.336	.473	.438	.497	.375	.399
1943	.269	.307	.414	.476	.467	.306	.373
1944	.216	.332	.477	.574	.515	.343	.410
1945	.205	.317	.388	.496	.496	.326	.371
1946	.262	.312	.466	.518	.481	.427	.411
1947	.233	.332	.474	.506	.473	.321	.390
1948	.212	.323	.476	.510	.490	.363	.395
1949	.227	.403	.494	.540	.523	.358	.424
1950	.166	.274	.350	.496	.523	.392	.367
Average	0.221	0.350	0.443	0.490	0.486	0.369	0.388

[1] Interpolated.

TABLE 26.—*Annual and average yields in bushels of winter wheat grown under different sequences and tillage methods, Colby (Kans.), 1915–50* [1]

Treatment and previous crop	Number of plots	Annual acre yields in—															
		1915	1916	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Early-plowed:																	
Winter wheat, continuous	1	18.7	18.5	5.3	7.5	15.0	13.2	15.3	5.0	8.5	5.5	1.3	0.7	18.3	5.8	29.0	6.0
Winter wheat in rotation	2	------	------	11.9	13.4	15.3	13.8	15.9	9.5	13.8	6.6	2.9	1.6	16.3	9.1	22.1	12.6
Early-plowed, shallow:																	
Winter wheat in rotation	1	------	------	------	------	14.8	9.6	14.4	7.8	10.6	7.5	1.3	0	15.0	9.0	15.3	13.7
Barley in rotation	1	------	------	------	------	14.2	8.2	12.2	6.8	14.0	2.7	1.0	0	11.8	9.0	15.7	10.7
Early-listed:																	
Winter wheat in rotation	1	------	------	------	------	14.3	11.1	16.1	6.8	8.1	5.7	3.3	0	16.2	9.7	20.3	14.7
Barley in rotation	1	------	------	------	------	14.5	8.7	14.3	6.3	12.7	6.7	.7	0	16.3	9.3	14.5	10.3
Late-plowed, shallow:																	
Winter wheat, continuous	1	9.3	9.0	11.2	25.8	20.0	23.8	12.4	10.0	10.5	5.2	1.7	1.7	19.8	5.3	26.7	9.0
Stubbled-in:																	
Winter wheat, continuous	1	------	------	------	------	------	12.6	8.1	15.5	1.1	5.8	2.3	3.3	12.7	5.0	12.3	11.2
Winter wheat in rotation	1	------	------	2.2	22.2	24.2	11.2	10.6	14.3	4.5	6.3	1.5	2.3	22.2	11.3	17.7	9.2
Following a row crop:																	
Milo, binder-harvested [2]	1	------	------	6.5	31.3	16.0	12.3	7.8	10.8	7.3	21.7	1.3	1.7	23.3	15.3	26.7	10.2
Corn, binder-harvested, 40-in. rows	2	------	------	6.0	21.7	16.6	7.8	9.6	8.1	11.5	10.3	1.5	3.1	18.3	10.8	30.1	12.6
Corn, stalks left standing	9	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Corn, binder-harvested, 80-in. rows	1	16.7	16.7	6.5	17.0	30.5	12.5	16.6	6.3	15.6	11.5	4.0	2.5	25.3	12.3	37.3	15.8
Beans	1	------	------	------	------	18.8	23.7	17.5	10.7	16.3	12.3	2.0	2.3	22.6	12.3	32.8	14.2
Green manure:																	
Rye plowed under	1	22.7	23.3	20.7	30.7	27.7	31.2	30.3	8.2	21.4	12.5	17.2	4.8	28.7	14.0	43.0	18.0
Fallow:																	
Summer-tilled	30	26.2	22.7	19.8	33.3	38.1	29.2	26.9	3.6	28.2	22.9	19.0	3.1	34.6	16.1	37.5	3.2

Treatment and previous crop	Number of plots	Annual acre yields in—														Average	
		1932	1934	1937	1938	1939	1941	1942	1943	1944	1945	1946	1947	1948	1950	1915–1950	1920–1950
Early-plowed:																	
Winter wheat, continuous	1	6.0	0	1.7	4.7	2.5	10.0	15.5	5.5	12.7	7.8	4.3	24.7	1.2	7.0	7.7	7.3
Winter wheat in rotation	2	0	0	2.5	4.8	2.2	10.4	20.3	13.8	23.0	11.4	14.2	25.1	4.7	5.0	[3] 8.9	8.9
Early-plowed, shallow:																	
Winter wheat in rotation	1	0	0	1.2	5.5	1.2	11.5	28.7	15.3	10.0	5.7	11.2	19.2	9.0	1.0	------	7.7
Barley in rotation	1	0	0	1.2	7.2	4.0	11.5	28.7	19.8	16.2	4.3	12.5	20.0	4.3	3.7	------	7.7
Early-listed:																	
Winter wheat in rotation	1	0	0	1.5	8.2	2.5	15.2	28.2	16.0	12.5	15.0	10.0	22.0	8.5	3.3	------	8.7
Barley in rotation	1	0	0	1.7	4.4	0	11.7	26.7	19.0	13.3	9.7	9.3	14.7	6.5	.7	------	7.5
Late-plowed, shallow:																	
Winter wheat, continuous	1	0	0	1.2	5.3	1.2	11.8	23.7	12.8	9.3	12.3	2.0	29.8	2.8	6.0	8.9	8.5
Stubbled-in:																	
Winter wheat, continuous	1	6.0	0	1.0	.3	0	3.8	6.2	4.0	10.3	6.8	1.5	4.2	.8	0	------	[4] 4.5
Winter wheat in rotation	1	4.5	0	2.5	3.0	1.2	7.3	21.2	11.3	9.2	18.2	6.2	22.0	7.0	2.8	[3] 8.1	8.1
Following a row crop:																	
Milo, binder-harvested [2]	1	1.5	0	3.0	5.5	0	12.5	21.3	15.0	19.2	20.0	10.3	29.5	2.3	3.5	[3] 9.9	9.6
Corn, binder-harvested, 40-in. rows	2	0	0	4.1	4.5	.9	4.3	23.7	25.7	18.6	17.8	8.5	28.6	3.4	5.6	[3] 9.3	9.2
Corn, stalks left standing	9	15.0	1.2	2.3	6.2	0	14.3	29.6	18.9	14.8	14.1	5.5	26.2	7.7	8.4	------	[5] 8.6
Corn, binder-harvested, 80-in. rows	1	5.3	1.3	2.7	8.2	5.7	15.7	27.5	23.7	23.3	25.8	12.3	33.7	20.2	11.8	12.9	13.1
Beans	1	0	0	2.3	7.6	0	15.2	27.0	21.5	18.3	4.3	9.3	35.7	6.0	10.0	------	11.1
Green manure:																	
Rye plowed under	1	22.0	1.7	1.7	6.8	4.3	14.8	30.7	18.7	37.7	44.5	22.2	37.3	------	------	[6] 18.1	------
Fallow:																	
Summer-tilled	30	31.8	10.0	3.9	9.2	6.0	22.3	25.2	27.6	33.2	38.7	24.8	36.5	19.4	25.3	19.6	19.5

[1] All treatments failed in 1917, 1933, 1935, 1936, and 1940. The crop was hailed out in 1949. These years are omitted from the body of the table but are included in the averages.

[2] Binder harvested, 1917–37; stalks left standing, 1938–50.

[3] Average is for 34 years, 1917–50.

[4] Average is for 30 years, 1921–50.

[5] Average is for 19 years, 1932–50.

[6] Average is for 33 years, 1915–47.

Table 27.—*Annual and average acre yields in bushels of winter wheat on land plowed at different intervals, and stubbled-in or shallow cultivated*[1] *when not plowed, Colby (Kans.), 1932–50*[2]

Treatment	Rotation	Annual yields in—														Average yield
		1932	1934	1937	1938	1939	1941	1942	1943	1944	1945	1946	1947	1948	1950	
Plowed every—																
Year	[3] SB6	33.0	0	1.7	5.3	2.8	11.8	19.8	10.7	12.3	14.5	8.8	19.8	3.3	6.2	7.9
Second year	[3] SBA6	39.0	0	1.5	6.3	2.7	12.5	32.7	12.2	33.3	25.0	15.8	27.7	13.8	15.7	12.5
Third year	609	29.5	0	1.2	5.8	1.3	9.8	20.5	11.8	24.7	29.8	12.3	24.0	13.0	15.7	11.0
Fourth year	610	31.8	2.0	.5	5.7	3.3	10.5	27.3	10.8	25.8	37.0	17.2	28.3	14.2	15.3	11.6
Fifth year	611	24.2	0	.5	6.0	2.2	12.7	18.7	12.7	24.7	27.2	19.2	20.0	8.3	19.7	10.3
First year of shallow cultivation following plowing	[3] SBA6	32.7	0	.8	5.8	.8	19.2	14.5	2.0	11.7	14.0	7.3	23.7	6.5	1.7	7.4
	609	32.7	0	.3	5.0	.8	11.7	24.7	10.8	19.0	13.2	9.3	33.3	9.0	2.2	9.1
	610	36.5	0	.5	5.5	2.7	11.5	20.3	7.3	11.5	12.8	8.7	24.5	9.2	1.5	8.0
	611	33.3	0	.3	5.5	.7	13.7	26.3	7.5	7.3	12.5	9.5	25.5	5.8	2.5	7.9
Second year of shallow cultivation following plowing	609	36.8	0	.3	5.8	1.2	11.8	19.5	15.7	19.0	17.5	9.2	31.2	9.0	7.8	9.7
	610	32.8	0	.5	6.8	1.2	15.0	29.2	10.3	19.7	17.2	10.0	28.0	8.7	9.2	9.2
	611	37.5	0	.3	6.3	.8	14.2	28.8	12.7	23.3	15.0	7.8	28.2	11.0	5.5	10.1
Third year of shallow cultivation following plowing	610	34.5	0	.3	6.5	4.5	15.5	22.8	8.2	21.2	12.2	9.3	26.2	8.3	9.0	9.4
	611	36.7	0	.3	5.7	1.3	13.7	25.7	10.7	16.5	15.2	8.0	24.8	9.2	5.5	9.1
Fourth year of shallow cultivation following plowing	611	31.0	0	.3	5.8	1.5	11.8	26.5	6.0	18.0	13.2	9.7	24.7	9.0	9.7	8.8

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[1] Stubbled-in, 1932-33, 1935, 1937, 1939, 1942–44; one-wayed, 1934, 1936, 1938, 1940–41, 1945–46; undercut with sweeps, 1947–50.

[2] All treatments failed in 1933, 1935, 1936, and 1940. The crop was damaged by hail in 1949. These years are included in the averages.

[3] The symbol "SB" means "Seedbed (continuous)" on the rotation chart; "SBA" means "Seedbed (alternate)." (See fig. 2.)

TABLE 28.—*Yields in bushels of continuous winter wheat under 6 different cultural practices used each year on the same land, and under 10 different cultural practices that are compared with uniform treatments the same years, Colby (Kans.), 1932–50* [1]

Tillage practice (a) for variable treatment year and (b)[2] for uniform plot, same year	Annual yields in—														Average yield
	1932	1934	1937	1938	1939	1941	1942	1943	1944	1945	1946	1947	1948	1950	
Continuous methods:															
(a) Listed, deep, early	24.7	0	1.0	6.0	2.3	14.0	23.2	13.5	22.0	19.2	8.7	32.7	8.8	2.0	9.4
(a) One-wayed, shallow, early	35.5	0	2.2	5.3	2.5	12.7	25.5	13.2	24.7	17.5	10.2	30.5	7.5	.7	9.9
(a) One-wayed, deep, early	34.7	0	1.7	5.2	2.3	13.3	22.2	12.0	19.2	18.7	8.7	32.8	5.3	1.3	9.3
(a) Disk-plowed, deep, early [3]	39.2	0	1.8	5.8	3.7	11.8	19.8	10.2	18.0	19.8	10.0	34.7	9.2	6.2	10.0
(a) Moldboard-plowed, shallow, early	39.2	0	2.0	6.2	2.8	12.2	16.8	9.8	14.3	14.3	7.5	23.7	2.8	6.3	8.3
(a) Moldboard-plowed, deep, early	33.0	0	1.7	5.3	2.8	11.8	19.8	10.7	12.3	14.5	8.8	19.8	3.3	6.2	7.9
Alternate methods:															
(a) Listed, deep, early	25.8	0	1.8	6.2	0	16.8	23.5	12.5	25.8	29.5	9.8	29.7	8.2	11.7	10.6
(b) Surface-cultivated	28.0	0	.8	7.0	1.8	15.0	26.2	3.0	7.7	14.2	7.0	32.5	6.8	.8	7.9
(a) One-wayed, shallow, early	39.8	1.8	2.2	5.7	1.0	15.7	33.2	10.5	28.2	28.7	13.5	29.0	11.2	.8	11.6
(b) Surface-cultivated	28.0	0	1.0	6.7	1.0	16.7	24.0	2.5	7.8	13.8	6.7	24.5	10.2	1.0	7.6
(a) One-wayed, deep, early	38.8	3.3	2.0	7.3	2.7	14.7	30.2	10.8	32.2	32.5	13.3	30.7	17.3	5.8	12.7
(b) Surface-cultivated	30.3	0	1.5	6.7	2.0	17.5	22.8	2.3	8.8	15.3	7.8	25.0	8.8	2.2	7.9
(a) Disk-plowed, deep, early [3]	41.3	2.7	1.8	8.7	2.3	12.7	30.5	10.5	30.3	30.8	12.5	28.0	12.3	6.2	12.1
(b) Surface-cultivated	36.5	0	1.8	5.2	2.2	17.0	20.8	2.5	7.7	13.2	6.8	25.5	12.7	5.2	8.3
(a) Moldboard-plowed, shallow, early	43.0	0	1.7	6.3	2.5	12.7	30.7	10.3	32.0	28.3	14.0	33.3	11.5	17.5	12.8
(b) Surface-cultivated	38.3	0	1.7	6.3	.8	18.5	16.7	2.8	11.0	12.2	6.5	22.5	6.2	2.0	7.7
(a) Moldboard-plowed, deep, early	39.0	0	1.5	6.3	2.7	12.5	32.7	12.2	33.3	25.0	15.8	27.7	13.8	15.7	12.5
(b) Surface-cultivated	32.7	0	.8	5.8	.8	19.2	14.5	2.0	11.7	14.0	7.3	23.7	6.5	1.7	7.4
(a) Moldboard-plowed, shallow, mid-August	33.5	0	2.0	8.7	2.0	15.8	31.5	15.5	29.5	16.7	13.2	18.0	12.3	11.0	11.0
(b) Surface-cultivated	35.5	0	.7	7.0	4.0	18.0	27.7	2.3	6.2	13.2	7.0	22.7	7.3	1.2	8.0
(a) Moldboard-plowed, deep, mid-August	26.7	0	1.7	5.3	1.7	15.0	30.7	16.3	26.7	14.8	13.2	21.2	10.2	11.3	10.3
(b) Surface-cultivated	33.2	0	.7	6.7	3.0	15.5	25.0	2.8	7.8	15.0	8.5	29.8	6.2	1.5	8.2
(a) Moldboard-plowed, shallow, mid-September	23.5	0	1.3	7.3	1.3	9.5	27.7	9.0	16.7	12.0	6.5	17.3	9.3	9.8	8.0
(b) Surface-cultivated	29.7	0	.7	7.7	3.2	17.3	20.0	3.7	7.0	12.7	7.5	23.8	9.2	2.0	7.6
(a) Moldboard-plowed, deep, mid-September	24.5	0	.8	6.3	1.3	7.8	24.3	12.7	18.8	13.5	4.7	22.8	7.0	8.5	8.1
(b) Surface-cultivated	32.3	0	.8	5.8	1.7	15.7	19.3	6.3	10.8	12.8	7.7	24.8	6.3	1.8	7.7

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[1] All treatments failed in 1933, 1935, 1936, and 1940, and the crop was damaged by hail in 1949. These years are included in the averages.

[2] All (b) plots were stubbled-in, in 1932–33, 1935, 1937, 1942–44; one-wayed 1934, 1936, 1938, 1940–41, 1945–46; undercut with sweeps, 1947–50. Tillage was performed early, if needed.

[3] Disk plowed, 1932–46, undercut with sweeps, 1947–50.

TABLE 29.—*Yields in bushels of winter wheat in a 2-year rotation, comparing the results of packing and not packing; in three 3-year rotations with and without stubble burning; and on a plot manured each year; Colby (Kans.), 1932–50* [1]

Rotation and treatment	Rotation	Annual acres yields in—														Average yield
		1932	1934	1937	1938	1939	1941	1942	1943	1944	1945	1946	1947	1948	1950	
2-year rotation of wheat, wheat: [2]																
Early-fall-plowed, packed	565	11.7	0	1.5	4.5	2.5	9.2	15.3	8.0	13.0	12.5	6.3	20.2	1.0	5.3	5.8
Early-fall-plowed, not packed	565	0	0	1.8	5.9	2.3	12.0	14.0	8.0	23.2	11.3	8.0	11.2	1.0	4.3	5.4
3-year rotations of fallow, wheat, wheat:																
Wheat on fallowed land—																
May-plowed	121–1	21.3	13.2	2.0	9.2	4.8	16.8	32.2	26.7	30.5	33.5	20.7	28.2	7.8	19.3	14.0
May-plowed	121–2	31.2	17.5	3.3	9.7	4.0	18.0	32.3	29.8	34.7	39.3	26.3	28.0	6.2	22.2	15.9
May-plowed	568	24.7	10.3	1.8	7.5	3.2	11.7	27.7	22.2	31.3	33.8	22.7	32.8	6.3	21.5	13.6
Second crop of wheat after fallow—																
Burned and one-wayed at harvest	121–1	18.5	0	1.5	5.8	1.5	11.8	28.8	16.5	8.7	11.2	7.8	28.7	5.0	3.7	7.9
Burned at seeding	121–2	30.3	0	2.3	8.2	1.3	17.0	34.2	16.5	19.3	12.7	5.7	17.8	5.8	10.0	9.5
Stubbled-in or shallow-cultivated	568	24.0	0	.5	5.9	0	11.2	23.0	8.0	18.3	12.0	8.2	29.8	8.3	3.8	8.1
Continuous wheat:																
Early-fall-plowed, topdressed with manure in winter	564	27.0	0	1.7	5.7	3.3	12.0	20.8	10.2	14.8	12.2	5.5	23.3	1.7	8.7	7.7

[1] All treatments failed in 1933, 1935, 1936, and 1940, and the crop was damaged by hail in 1949. These years are included in the average.

[2] The 2 methods were in rotation and were packed or not packed in alternate years.

TABLE 30.—*Annual and average yields in bushels of winter wheat on land alternately fallowed by different methods and cropped, Colby (Kans.), 1922–50* [1]

Method of fallow	Plot	Acre yields in—												
		1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1934	1937
Plowed soon after harvest, worked down, replowed in June	H-I	32.5	1.5	33.5	21.3	6.5	1.0	30.5	13.0	31.3	31.2	26.8	3.7	8.5
Plowed late in fall, left rough over winter	J-K	31.8	1.7	47.5	19.2	9.5	.5	33.2	13.2	35.3	34.2	35.3	3.2	6.5
Left in stubble over winter, plowed about May 15	L-M	25.3	1.0	39.9	24.0	8.8	.3	34.7	17.7	34.0	34.8	30.8	5.5	6.5
Left in stubble over winter, plowed about June 15	N-O	16.6	2.2	33.3	11.5	7.3	.2	20.7	12.3	39.2	29.2	20.0	1.5	3.3
Late fall listed, ridges leveled about May 15	P-Q	31.3	2.5	37.8	23.3	14.3	2.3	41.2	14.7	41.5	25.7	38.2	7.7	7.8

Method of fallow	Plot	Acre yields in—											Average yield
		1938	1939	1941	1942	1943	1944	1945	1946	1947	1948	1950	
Plowed soon after harvest, worked down, replowed in June	H-I	8.7	5.3	20.0	16.0	27.7	27.3	42.2	11.2	39.3	23.2	20.0	16.6
Plowed late in fall, left rough over winter	J-K	8.2	5.5	19.3	16.7	30.8	28.2	44.8	8.3	35.8	28.8	24.0	18.0
Left in stubble over winter, plowed about May 15	L-M	7.5	6.0	23.0	20.0	32.5	29.8	42.8	14.3	31.5	25.3	26.5	18.0
Left in stubble over winter, plowed about June 15	N-O	5.0	5.5	12.7	22.7	18.7	27.3	33.5	11.5	28.7	21.7	29.5	14.3
Late fall listed, ridges leveled about May 15	P-Q	7.6	9.2	21.3	20.3	30.5	38.2	37.3	20.3	39.0	23.0	24.5	19.3

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[1] All treatments failed in 1933, 1935, 1936, and 1940. The crop was damaged by hail in 1949. These years are included in the average.

TABLE 31.—*Annual and average yields in bushels of winter wheat in 3-year rotations of fallow, wheat, wheat, in which the fallow was tilled by different methods, Colby (Kans.), 1932–50* [1]

Preparation of fallow for first crop of wheat (a); preparation for second crop of wheat (b) [2]	Acre yields in—														Average yields	
	1932	1934	1937	1938	1939	1941	1942	1943	1944	1945	1946	1947	1948	1950	1st year after fallow	2d year after fallow
(a) Duckfooted or subsurface-cultivated early	35.5	24.3	3.3	12.3	3.3	31.3	21.5	31.7	37.2	33.3	30.2	38.3	16.7	29.8	18.4	--------
(b) Shallow-tilled	32.8	0	.7	5.7	4.3	15.0	28.7	2.8	17.7	12.0	5.2	30.3	6.0	3.0	--------	8.6
(a) One-wayed early	33.3	27.5	4.0	13.8	3.3	29.8	25.7	32.0	36.2	35.2	31.8	40.2	26.8	31.8	19.5	--------
(b) Shallow-tilled	30.5	0	1.2	8.7	3.7	16.3	29.2	2.5	13.7	10.7	5.2	28.2	6.3	1.5	--------	8.3
(a) Plowed in May	41.0	26.3	3.7	9.8	1.8	27.8	23.2	31.2	37.7	43.8	33.2	44.3	28.5	31.7	20.2	--------
(b) Shallow-tilled	29.8	0	1.2	6.5	3.7	16.7	29.3	2.8	17.5	11.5	5.5	30.0	6.7	2.2	--------	8.6
(a) One-wayed early, listed in May	41.8	27.2	4.5	11.7	2.5	26.7	23.7	31.3	35.8	40.0	33.3	40.8	29.7	28.8	19.9	--------
(b) Shallow-tilled	35.0	0	1.2	5.3	4.7	17.2	27.0	2.8	16.3	11.5	5.5	26.8	6.8	1.8	--------	8.5
(a) Listed in May	41.8	26.3	3.8	11.2	3.3	25.3	26.8	33.0	32.7	38.2	33.3	44.0	23.3	31.8	19.7	--------
(b) Shallow-tilled	35.3	0	.8	6.2	4.0	17.0	28.8	2.7	15.3	12.5	6.3	30.7	10.7	2.2	--------	9.1
(a) Listed early, relisted in May	39.0	22.5	3.0	10.7	2.0	24.2	23.3	32.0	35.8	38.2	35.5	44.5	25.2	31.8	19.4	--------
(b) Shallow-tilled	30.2	0	.7	5.0	3.3	17.2	26.5	2.3	15.2	14.3	7.2	28.0	9.2	1.7	--------	8.5
(a) One-wayed early, plowed in May	40.8	21.3	2.3	11.0	3.8	20.8	21.2	31.0	33.5	40.7	30.7	44.7	27.5	33.5	19.1	--------
(b) Shallow-tilled	35.5	0	.5	5.2	1.8	15.3	25.7	2.5	21.3	13.3	10.8	34.2	7.5	2.0	--------	9.2
(a) Plowed in May	39.5	20.3	1.5	10.5	4.2	21.3	22.5	30.3	33.3	41.0	29.3	45.7	27.3	33.7	19.0	--------
(b) Shallow-tilled	34.0	0	.5	5.0	1.7	14.8	29.8	2.8	21.0	11.3	9.2	32.3	8.7	2.0	--------	9.1
(a) Plowed in June	34.2	14.7	.8	7.2	3.3	17.8	23.3	29.2	30.0	36.2	27.0	42.7	18.2	30.7	16.6	--------
(b) Shallow-tilled	28.5	0	.5	6.2	1.0	17.2	25.5	3.5	15.7	10.2	9.2	29.8	8.5	1.3	--------	8.3
(a) One-wayed early, plowed in June	34.5	9.7	1.0	11.5	3.3	18.2	20.0	27.0	26.8	27.8	23.5	38.7	19.7	23.7	15.0	--------
(b) Shallow-tilled	29.0	0	.3	4.2	1.5	13.3	24.3	3.8	24.3	14.3	10.7	34.0	5.3	1.7	--------	8.8

[1] The crop failed in 1933, 1935, 1936, and 1940. It was damaged by hail in 1949. These years are included in the average.

[2] All (b) plots were stubbled-in, 1932–33, 1935, 1937, 1939, and 1942–44; one-wayed, 1934 1936, 1938 1940–41, and 1945–46; undercut with sweeps, 1947–50.

TABLE 32.—*Annual and average yields in bushels of winter wheat in a group of miscellaneous rotations, Colby (Kans.), 1932–50*[1]

Preparation of fallow for first crop of wheat (a); preparation for second crop of wheat (b); preparation for third crop of wheat (c); preparation for continuous wheat (d)	Rotation	Acre yields in—															Average yield	
		1932	1934	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1950	1932–50	1939-50
(a) May-plowed, crop binder-harvested	566–1	28.0	3.7	1.0	5.3	3.0	0	19.3	31.2	15.8	27.0	22.0	15.0	25.8	1.7	11.3	11.1	-------
(b) Shallow-tilled [2]	566–1	20.7	0	.3	2.5	0	0	12.5	17.7	2.0	16.0	11.7	4.3	20.5	1.0	.8	5.8	-------
(c) Shallow-tilled [2]	566–1	14.3	0	.3	3.0	0	0	10.3	17.0	2.8	5.8	12.0	3.8	22.7	2.5	2.5	5.1	-------
(a) May-plowed, crop combine-harvested	566–2	32.8	7.0	1.5	6.1	3.5	0	20.5	27.2	21.0	34.0	26.7	20.0	35.0	8.3	19.7	13.9	-------
(b) Shallow-tilled [2]	566–2	30.0	0	.5	5.3	.7	0	14.2	25.0	7.8	18.8	14.8	9.2	33.8	7.5	2.8	9.0	-------
(c) Shallow-tilled [2]	566-2	26.7	0	.3	5.2	.5	0	11.3	30.8	8.8	28.2	19.5	7.8	28.0	8.8	6.2	9.6	-------
(a) 2-year fallow	[3]MF11	-------	-------	-------	-------	[4]0	6.5	28.8	26.0	28.5	33.2	35.5	33.0	34.0	20.7	23.5	-------	22.5
(b) Shallow-tilled [2]	[3]MF11	-------	-------	-------	-------	5.8	1.8	12.0	25.2	2.8	13.3	15.5	6.5	41.3	15.7	6.3	-------	12.2
(a) May-listed	[5]SC3	-------	-------	-------	-------	1.8	0	23.2	18.0	26.8	29.2	41.5	29.2	36.7	11.7	27.7	-------	20.5
(b) Early-listed	[5]SC3	-------	-------	-------	-------	1.2	0	19.3	18.8	8.2	30.2	29.0	7.8	40.7	7.0	17.3	-------	15.0
(a) May-basin-listed	[5]SC4	-------	-------	-------	-------	5.2	0	23.3	17.3	30.2	25.8	36.3	30.7	32.5	17.2	24.5	-------	20.2
(b) Early-basin-listed	[5]SC4	-------	-------	-------	-------	.8	0	20.2	19.3	6.0	27.8	25.5	9.2	38.8	7.8	20.5	-------	14.7
(a) May-plowed, land diked to prevent runoff	[5]SC2	-------	-------	-------	-------	8.3	0	25.0	19.5	21.0	30.3	46.0	30.2	35.3	17.7	24.2	-------	21.5
(b) Shallow-tilled,[2] land diked to prevent runoff	[5]SC2	-------	-------	-------	-------	3.8	0	17.0	21.0	2.2	15.5	30.2	11.5	29.5	6.3	5.7	-------	11.9
(d) Shallow-tilled [2]	[5]SC1	-------	-------	-------	-------	6.0	0	15.8	25.5	2.2	20.2	28.8	7.0	29.3	8.8	1.3	-------	12.1

[1] The crop failed on all treatments in 1933, 1935, 1936, and 1941. It was damaged by hail in 1949. These years are included in the average.

[2] Stubbled-in, 1932–33, 1935, 1937, 1939, and 1942–44; one-wayed, 1934, 1936, 1938, 1940–41, and 1945–46; undercut with sweeps, 1947–50.

[3] The symbol "MF" means "Methods of fallow" on the rotation chart. (See fig. 2.)

[4] A thin stand of wheat survived the winter but was destroyed by rabbits and grasshoppers.

[5] The symbol "SC" means "Soil-culture plots" on the rotation chart. (See fig. 2.)

TABLE 33.—*Annual and average yields in bushels of oats and barley grown under different sequence and tillage practices, Colby (Kans.), 1915–50*[1]

Crop, tillage treatment, and previous crop	Number of plots	Acre yelds in—																
		1915	1916	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932
Oats:																		
Spring-plowed—																		
Oats	1	37.5	4.7	0	34.1	21.9	18.1	12.7	42.5	12.7	11.3	0	12.2	28.8	15.9	52.5	4.7	26.6
Spring wheat	1	33.1	9.1	0	27.2	37.8	21.3	17.3	57.5	16.1	14.7	0	15.6	17.2	13.1	54.1	15.0	35.6
Corn	2	47.0	2.5	0	13.0	26.1	19.9	5.4	37.1	12.7	5.8	0	4.2	13.8	8.9	49.3	5.3	27.9
Early-fall-plowed—																		
Oats	1	53.4	6.6	0	27.5	26.9	17.2	19.8	45.0	17.2	8.1	0	8.4	40.6	8.4	56.9	6.6	29.1
Spring wheat	3	49.9	5.1	0	25.1	32.2	25.0	18.6	43.2	18.1	5.5	0	5.4	26.4	9.1	53.7	16.5	21.0
Barley	1	41.3	5.0	0	14.1	28.1	23.6	5.5	42.5	12.7	2.5	0	3.1	18.8	6.9	38.8	17.5	20.9
Disked—																		
Corn	1	48.8	8.1	0	23.8	35.9	21.6	25.8	31.6	13.7	5.6	0	6.9	18.1	20.6	53.8	13.1	25.0
Fallow	2	65.2	10.4	0	26.4	49.9	33.2	27.7	65.3	26.7	30.7	3.6	13.1	46.7	21.4	74.9	14.7	58.2
Barley:																		
Spring-plowed—																		
Barley	1	42.3	2.3	4.4	37.5	29.2	18.1	19.1	43.3	14.8	13.5	0	9.8	36.5	21.7	45.0	6.0	12.9
Oats	1	43.8	0	3.5	44.4	22.5	21.0	12.5	46.0	22.1	13.3	0	6.7	40.0	22.3	54.4	10.6	17.5
Early-fall-plowed—																		
Barley	1	41.7	14.8	7.1	42.7	27.5	25.2	32.5	36.0	20.0	8.3	0	1.9	45.2	12.7	52.9	7.9	20.4
Disked—																		
Corn	2	52.9	7.9	2.1	44.4	21.4	8.1	9.8	27.6	11.6	6.7	0	3.9	41.7	19.1	47.0	10.0	10.7
Milo	1	------	------	------	------	22.7	4.2	14.4	14.6	5.9	18.5	0	1.5	42.1	27.3	46.3	8.3	10.8
Standing corn stalks	1	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	22.3
Fallow	1	61.9	20.8	11.7	52.5	55.0	35.3	36.3	54.4	40.4	35.8	8.1	21.0	52.7	51.7	54.6	19.8	53.1

Crop, tillage treatment, and previous crop	Number of plots	Acre yields in—																Average yield
		1933	1934	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1950	
Oats:																		
Spring-plowed—																		
Oats	1	0	0	1.3	0.6	8.4	5.3	15.6	44.1	15.6	11.6	21.3	41.6	6.3	52.5	40.6	4.7	16.8
Spring wheat	1	.9	0	.9	1.9	8.4	8.1	9.7	37.5	8.4	13.4	20.6	46.9	3.1	58.1	32.8	5.9	17.8
Corn	2	0	0	1.0	3.0	8.3	6.0	5.5	25.0	11.7	7.7	14.7	33.9	3.8	64.1	7.8	5.8	13.3
Early-fall-plowed—																		
Oats	1	0	0	.9	.9	8.4	4.7	10.9	27.8	18.4	10.9	21.9	29.4	3.8	61.3	10.3	4.1	16.3
Spring wheat	3	0	0	1.6	1.3	7.4	3.1	9.9	21.7	13.3	12.5	17.1	27.8	3.3	73.2	5.8	5.0	15.5
Barley	1	0	0	.9	1.3	8.8	4.1	5.0	19.7	12.2	5.9	14.4	14.7	5.0	75.6	2.5	3.8	12.6
Disked—																		
Corn	1	0	0	1.3	3.8	6.9	7.2	7.2	26.3	11.3	7.5	16.9	26.9	2.5	69.4	6.6	8.4	15.4
Fallow	2	3.3	2.4	6.1	2.5	8.3	11.0	12.4	39.7	20.2	29.6	19.1	60.8	10.7	65.6	45.0	10.0	25.4
Barley:																		
Spring-plowed—																		
Barley	1	0	0	0	.6	4.2	6.0	8.1	32.3	16.5	17.1	22.3	26.0	2.9	25.8	15.6	2.7	14.9
Oats	1	0	0	0	.8	4.2	1.9	8.1	36.3	11.5	18.5	18.8	31.7	2.9	42.3	13.1	2.1	15.9
Early-fall-plowed—																		
Barley	1	0	0	0	.6	3.5	2.3	4.2	19.4	14.8	12.7	16.3	20.6	4.0	36.5	8.5	5.8	15.2
Disked—																		
Corn	2	0	0	0	2.1	5.1	3.9	9.0	21.5	14.7	15.7	17.1	18.4	3.4	39.1	8.5	5.7	13.6
Milo	1	0	0	0	3.3	2.9	5.0	6.5	28.1	19.2	17.7	15.2	17.1	3.5	28.8	13.1	5.2	[2] 12.3
Standing corn stalks	1	1.3	0	0	.6	2.1	6.9	7.9	31.7	17.5	17.7	22.3	19.6	4.0	25.8	10.2	5.6	[3] 10.3
Fallow	1	7.5	2.1	.6	1.5	5.0	6.3	7.1	34.6	28.1	24.2	26.5	54.2	16.0	44.4	27.7	13.1	26.8

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[1] All plots failed in 1917 and 1935, and the crop was hailed out in 1949. These years are included in the average.

[2] 31-year average, 1920–50.

[3] 19-year average, 1932–50.

TABLE 34.—*Annual and average yields in bushels of ear corn grown under different sequence and tillage practices, Colby (Kans.), 1915–50*[1]

Treatment and previous crop	Number of plots	Acre yields in—																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1927	1928	1929	1930	1931	1932
Spring-plowed:																		
Corn (continuous)	1	55.4	0	0	0	26.3	38.7	16.3	19.2	38.0	2.4	0	15.6	22.4	1.7	18.4	5.9	0
Spring wheat [2]	1	40.7	0	0	0	19.9	59.3	23.9	18.0	51.0	14.7	0	8.5	15.6	.4	14.0	16.5	6.1
Oats [2]	1	52.9	0	0	0	32.8	65.2	30.7	27.8	55.8	17.9	10.3	11.9	24.7	1.5	16.4	18.8	6.3
Barley [2]	1	42.7	0	0	0	17.5	47.7	18.1	14.9	50.2	10.6	0	3.6	13.1	.3	12.4	9.7	5.7
Early-fall-plowed:																		
Spring wheat [2]	1	46.1	0	0	0	22.6	61.6	25.7	21.6	37.1	3.6	0	8.4	21.6	.5	15.3	10.3	10.0
Oats [2]	3	44.2	0	0	0	19.5	52.9	21.4	15.3	39.2	3.8	0	2.7	16.9	.5	12.0	6.6	5.1
Late-fall-plowed:																		
Corn (continuous)	1	59.1	0	0	0	27.2	51.9	16.9	14.4	44.6	1.2	0	10.1	17.2	.7	25.9	2.5	0
Subsoiled:																		
Corn (continuous)	1	65.0	0	0	0	26.0	56.5	19.9	15.0	43.9	2.2	0	15.2	19.5	.8	23.6	6.8	0
Listed at planting, no prior cultivation:																		
Corn (continuous)	1	44.1	2.6	3.9	3.2	31.5	45.7	23.7	28.5	47.5	15.6	3.1	21.6	22.7	5.5	20.3	18.7	8.8
Milo	1	------	------	3.6	0	23.2	53.1	21.4	13.5	50.5	4.5	4.8	9.1	18.7	7.6	25.1	16.3	3.3
Winter wheat	1	------	------	2.4	0	25.3	50.3	30.7	31.7	48.1	8.5	5.7	8.4	17.3	3.2	26.9	17.3	7.1
Listed at planting, early-disked:																		
Corn (continuous)	1	42.1	2.0	3.0	6.0	29.4	53.9	25.6	30.0	53.9	12.4	2.3	20.3	24.5	7.7	22.8	19.6	9.7
Listed at planting, corn in 80-inch rows:																		
Milo	1	13.4	1.1	2.7	0	13.2	35.3	13.7	13.2	30.7	5.1	0	12.8	10.3	2.4	4.7	6.7	3.6
Winter wheat	1	23.0	.9	2.1	0	16.5	29.5	16.1	16.4	33.1	10.5	1.9	16.9	10.9	4.4	8.6	10.7	11.3
Fallowed:																		
Fallow [3]	1	64.4	3.6	4.9	6.9	43.6	52.7	36.7	37.9	56.4	21.6	14.0	24.4.	36.9	23.1	35.1	24.0	19.3
Diked, early-disked, lister-planted:																		
Corn (continuous)	1	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

Treatment and previous crop	Number of plots	Acre yields in—															Average yield
		1933	1935	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1915–50
Spring-plowed:																	
Corn (continuous)	1	6.5	0	1.5	0.8	1.5	24.9	25.6	2.6	27.9	15.7	3.1	3.0	7.1	8.4	14.3	11.2
Spring wheat [2]	1	2.4	0	.7	0	.5	33.7	29.0	1.3	35.3	10.3	1.9	3.9	16.1	1.6	8.1	12.0
Oats [2]	1	6.7	0	1.3	.7	1.7	40.0	27.6	4.7	38.7	10.3	6.0	3.6	21.4	6.1	15.3	15.7
Barley [2]	1	.5	0	.9	0	.5	29.2	21.3	.4	35.9	13.1	1.0	1.9	10.0	3.3	4.6	10.3
Early-fall-plowed:																	
Spring wheat [2]	1	4.3	0	1.6	0	.4	26.0	31.3	2.0	26.7	12.1	1.1	1.4	28.3	1.1	14.1	12.1
Oats [2]	3	.9	0	.7	0	.2	19.4	24.9	.5	24.9	9.4	1.0	2.0	20.3	1.5	18.0	10.1
Late-fall-plowed:																	
Corn (continuous)	1	2.3	0	1.1	0	1.2	19.7	26.1	2.0	30.6	11.6	2.7	3.6	9.0	8.1	9.0	11.1
Subsoiled:																	
Corn (continuous)	1	4.4	0	------	------	------	------	------	------	------	------	------	------	------	------	------	[4] 13.5
Listed at planting, no prior cultivation:																	
Corn (continuous)	1	12.4	2.5	2.9	4.5	4.8	24.8	31.0	7.3	32.3	22.3	5.1	.7	9.1	13.3	17.7	14.9
Milo	1	3.3	0	.9	.4	1.2	34.3	26.7	4.3	35.0	27.3	1.6	2.1	7.9	7.9	8.3	[5] 12.2
Winter wheat	1	2.1	0	1.5	1.3	1.5	38.0	31.9	9.1	38.7	27.0	1.3	7.6	24.3	10.4	13.1	[5] 14.4
Listed at planting, early-disked:																	
Corn (continuous)	1	12.1	1.7	2.9	2.0	2.1	29.5	31.6	8.7	32.4	22.7	6.4	1.9	7.4	6.1	29.0	15.6
Listed at planting, corn in 80-inch rows:																	
Milo	1	5.1	0	.1	0	1.5	13.5	13.0	3.6	23.1	21.3	5.0	2.4	11.7	1.0	8.4	7.7
Winter wheat	1	8.5	0	.1	0	1.2	20.1	16.7	4.6	26.4	22.4	5.0	4.3	17.0	1.9	8.3	9.7
Fallowed:																	
Fallow [3]	1	21.5	1.5	3.7	9.7	10.0	27.6	30.9	17.7	30.0	37.1	26.1	18.0	34.3	17.6	25.7	22.7
Diked, early-disked, lister-planted:																	
Corn (continuous)	1	------	------	3.2	4.9	2.1	31.2	29.4	7.6	35.7	26.0	8.7	3.1	12.1	13.7	20.1	[6] 14.1

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[1] Corn failed completely in 1926, 1934, 1936 and 1937. These years are included in the average.

[2] Surface-planted, 1915–30; lister-planted, 1931–50.

[3] Surface-planted, 1915–36; lister-planted, 1937–50.

[4] 22-year average, 1915–36.

[5] 34-year average, 1917–50.

[6] 14-year average, 1937–50.

Table 35.—*Annual and average yields in bushels of milo grown under different sequences and tillage practices, Colby (Kans.), 1915–50*[1]

Treatment and previous crop	Number of plots	Acre yields in—																
		1915	1917	1918	1919	1920	1921	1922	1923	1924	1925	1927	1928	1929	1930	1931	1932	1933
Spring-plowed, surface plantings:																		
Milo, continuous	1	11.4	3.4	7.1	27.6	18.3	15.7	17.0	30.9	4.7	6.0	5.0	11.2	1.7	14.8	32.9	0	6.7
Fall-plowed, surface planting:																		
Milo, continuous	1	12.6	3.1	9.1	28.8	20.7	15.9	12.3	44.8	6.7	1.6	7.9	11.7	1.4	27.2	14.5	0	2.1
Fall-plowed and subsoiled, surface-planted:																		
Milo, continuous	1	5.9	5.4	9.1	14.7	21.4	26.0	12.8	48.3	9.1	5.2	9.7	9.5	4.3	37.9	23.8	0	2.9
Listed at planting, no prior cultivation:																		
Milo, continuous	1	0	0	8.3	32.8	18.8	10.2	16.1	27.2	1.7	15.9	5.9	.7	7.1	24.8	41.9	11.2	9.5
Listed at planting, early-disked:																		
Milo, continuous	1	0	0	7.9	31.7	23.8	11.2	23.9	29.0	6.1	10.7	3.4	1.6	7.4	20.3	45.7	9.5	6.6
Winter wheat	13–23	0	1.3	3.4	33.5	20.5	20.2	17.5	41.7	3.9	6.2	7.2	6.5	4.7	35.9	34.7	18.6	21.6
Corn in 80-inch rows	1	0	0	6.9	31.2	25.3	26.3	13.2	27.2	5.1	15.7	9.8	3.6	2.2	19.1	42.8	34.7	17.1
Green manure:																		
Winter rye plowed under	2	4.3	4.3	17.6	32.8	54.6	36.9	31.3	52.5	27.8	7.5	19.0	17.0	13.6	38.6	34.2	16.7	14.7
Peas plowed under	1	4.8	9.3	17.2	29.5	53.1	36.5	37.4	50.3	28.8	18.1	12.1	21.6	16.6	35.0	38.3	38.4	12.2
Fallowed:																		
Fallow	3	7.0	8.8	12.7	26.2	53.7	48.	38.0	67.1	39.5	24.7	13.4	19.7	21.6	42.5	49.4	55.3	28.5
Listed at planting, early-disked, diked:																		
Milo, continuous	1	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

Treatment and previous crop	Number of plots	Acre yields in—													Average yields		
		1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1915–50	1915–37	1938–50
Spring-plowed, surface planting:																	
Milo, continuous	1	6.7	10.9	9.0	45.0	16.4	13.8	38.6	19.3	10.5	9.8	15.3	12.2	5.2	11.9	9.3	16.4
Fall-plowed, surface planting:																	
Milo, continuous	1	7.4	4.8	5.9	27.6	23.3	7.2	31.7	11.9	6.6	9.5	10.7	24.1	2.1	10.9	9.6	13.3
Fall-plowed and subsoiled, surface-planted:																	
Milo, continuous	1	------	------	------	------	------	------	------	------	------	------	------	------	------	------	[2] 10.7	------
Listed at planting, no prior cultivation:																	
Milo, continuous	1	1.7	11.0	5.5	36.0	13.8	8.6	31.6	6.0	1.2	10.0	16.9	1.0	10.3	10.7	10.1	11.8
Listed at planting, early-disked:																	
Milo, continuous	1	2.4	14.1	11.7	39.0	20.3	21.4	27.4	11.9	7.1	15.3	26.0	2.6	11.6	12.5	10.4	16.2
Winter wheat	13–23	10.0	5.8	8.9	36.4	23.5	6.3	34.9	14.7	3.9	12.4	24.5	10.8	5.9	13.2	12.1	15.2
Corn in 80-inch rows	1	10.5	5.9	7.6	38.1	21.6	16.2	37.1	12.1	2.6	4.8	29.5	7.8	14.1	13.6	12.2	16.0
Green manure:																	
Winter rye plowed under	2	13.9	6.5	3.5	33.5	33.4	25.0	33.1	33.6	21.0	13.2	------	------	------	[3] 19.4	18.4	[4] 21.7
Peas plowed under	1	15.3	7.8	3.8	31.9	33.1	28.4	29.3	24.3	23.1	23.6	------	------	------	[3] 20.6	20.0	[4] 22.1
Fallowed:																	
Fallow	3	13.7	12.0	19.6	51.9	30.7	30.3	37.2	32.0	25.0	18.9	37.3	35.0	38.1	26.1	24.2	29.4
Listed at planting, early-disked, diked:																	
Milo, continuous	1	4.5	13.8	12.1	44.1	22.8	21.4	28.8	17.2	10.3	14.7	30.7	4.8	12.9	------	------	18.3

[1] Crop failed completely in 1916, 1926, 1934–37. These years are included in the average.

[2] 23-year average. The treatment was actually discontinued in 1936, but the 1937 yield is included as zero.

[3] 33-year average, 1915–47.

[4] 10-year average, 1938–47.

TABLE 36.—*Quantities of available water in the soil*[1] *at seeding time, and yields of winter wheat on 3 methods of cultivation, Colby (Kans.), 1915–50*

Amounts of water at seeding time (inches)				Date seeded	Date soil sampled	Yield (bushels)		
Crop year	Early-plowed	Late-plowed	Fallowed			Early-plowed	Late-plowed	Fallowed
1915	1.1	3.2	4.0	Sept. 16	Oct. 9	9	19	20
1916	2.5	3.3	6.0	Sept. 16	Sept. 20	9	19	26
1917	.1	.1	1.4	Sept. 18	Sept. 20	0	0	0
1918	3.7	3.2	5.1	Sept. 20	Sept. 28	11	5	8
1919	1.1	1.2	1.1	Sept. 18	Sept. 24	26	8	14
1920	.8	1.6	5.9	Sept. 24	Oct. 30	20	15	32
1921	2.1	1.5	5.8	Sept. 14	----------	24	13	25
1922	.8	.6	3.1	Sept. 21	Oct. 19	12	15	18
1923	0	.6	3.9	Sept. 21	Oct. 18	10	5	2
1924	2.6	2.3	7.8	Sept. 20	Nov. 1	11	9	32
1925	.6	1.7	7.1	Sept. 24	Sept. 25	5	6	28
1926	.8	1.3	3.0	Sept. 18	Sept. 24	2	1	13
1927	0	0	1.4	Sept. 15	Sept. 20	2	1	3
1928	.9	1.3	6.0	Sept. 19	Sept. 30	20	18	38
1929	.6	1.4	7.5	Sept. 22	Oct. 16	5	6	14
1930	1.5	1.1	4.8	Sept. 18	Sept. 23	27	29	43
1931	1.1	.7	8.8	Sept. 16	Sept. 22	9	6	23
1932	.5	1.6	8.1	Sept. 16	Oct. 14	0	6	37
1933	.2	.4	6.1	Sept. 19	Nov. 21	0	0	0
1934	1.0	2.4	6.9	Sept. 18	Sept. 20	0	0	6
1935	.1	.6	1.9	Sept. 18	Sept. 21	0	0	0
1936	.6	.7	2.9	Sept. 23	Sept. 30	0	0	0
1937	1.0	1.3	2.7	Oct. 2	Oct. 5	1	2	3
1938	.3	.3	1.1	Sept. 16	Sept. 18	5	5	5
1939	1.1	1.0	2.5	Sept. 16	Sept. 26	1	3	4
1940	0	.1	2.5	Nov. 21	Nov. 20	0	0	0
1941	.6	.4	4.1	Sept. 17	Sept. 18	12	10	23
1942	4.7	4.6	8.6	Oct. 3	Oct. 6	24	16	22
1943	2.3	2.1	9.2	Sept. 16	Sept. 19	13	6	29
1944	0	.5	2.7	Sept. 16	Sept. 18	9	13	31
1945	1.0	.5	9.9	Sept. 16	Oct. 7	12	8	41
1946	.7	1.6	6.6	Sept. 18	Oct. 13	2	4	16
1947	3.7	2.8	5.7	Sept. 18	Oct. 24	30	25	46
1948	1.2	.8	7.7	Sept. 17	Dec. 29	3	1	10
1949	[2] 2.6	[2] 2.8	[2] 7.8	Sept. 17	Apr. 18	(3)	(3)	(3)
1950	2.5	2.3	9.8	Sept. 19	Oct. 15	6	7	23

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[1] Moisture determinations on early- and late-plowed ground were made to a depth of 3 feet and on fallow to a depth of 6 feet.

[2] Not used in correlations.

[3] Hailed.

TABLE 37.—*Depth to which soil was wet at winter-wheat seeding time, Colby (Kans.), 1915–50* [1]

Crop year	Late plowed				Early plowed				Fallowed					
	Depth (feet)				Depth (feet)				Depth (feet)					
	1	2	3	4	1	2	3	4	1	2	3	4	5	6
1915	x	—	—	—	x	x	x	—	x	x	x	—	—	—
1916	x	x	x	x	x	x	x	x	x	x	x	x	x	—
1917	—	—	—	—	—	—	—	—	x	—	—	—	—	—
1918	x	x	—	—	x	x	—	—	x	x	x	x	—	—
1919	x	—	—	—	x	—	—	—	x	—	—	—	—	—
1920	x	—	—	—	x	—	—	—	x	x	x	x	x	—
1921	x	x	x	—	x	x	x	—	x	x	x	x	x	—
1922	x	—	—	—	x	—	—	—	x	x	—	—	—	—
1923	—	—	—	—	x	—	—	—	x	x	x	—	—	—
1924	x	—	—	—	x	x	—	—	x	x	x	x	x	x
1925	x	—	—	—	x	—	—	—	x	x	x	x	x	—
1926	x	—	—	—	x	—	—	—	x	x	—	—	—	—
1927	—	—	—	—	—	—	—	—	x	—	—	—	—	—
1928	x	—	—	—	x	—	—	—	x	x	x	x	—	—
1929	x	—	—	—	x	—	—	—	x	x	x	x	x	x
1930	x	—	—	—	x	—	—	—	x	x	x	—	—	—
1931	x	—	—	—	x	—	—	—	x	x	x	x	x	x
1932	—	—	—	—	x	x	—	—	x	x	x	x	x	x
1933	—	—	—	—	—	—	—	—	x	x	x	x	x	—
1934	x	—	—	—	x	x	—	—	x	x	x	x	—	—
1935	—	—	—	—	—	—	—	—	x	x	—	—	—	—
1936	x	—	—	—	x	—	—	—	x	x	—	—	—	—
1937	x	—	—	—	x	—	—	—	x	x	—	—	—	—
1938	—	—	—	—	—	—	—	—	x	—	—	—	—	—
1939	x	—	—	—	x	—	—	—	x	x	—	—	—	—
1940	—	—	—	—	—	—	—	—	x	x	x	—	—	—
1941	x	—	—	—	x	—	—	—	x	x	x	—	—	—
1942	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1943	x	x	—	—	x	x	—	—	x	x	x	x	x	x
1944	—	—	—	—	—	—	—	—	x	x	—	—	—	—
1945	x	—	—	—	—	—	—	—	x	x	x	x	x	x
1946	—	—	—	—	x	—	—	—	x	x	x	x	—	—
1947	x	x	—	—	x	x	—	—	x	x	x	—	—	—
1948	x	—	—	—	x	—	—	—	x	x	x	x	x	x
1949	x	—	—	—	x	x	—	—	x	x	x	x	x	x
1950	x	x	—	x	x	x	—	x	x	x	x	x	x	x

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[1] The symbol "x" represents 3 percent or more of available moisture; the dashes represent less than 3 percent.

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